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A Study of the Pollution Sources and Their Effect on the Aquatic Habitat of Eagle Creek Watershed, Apache-Sitgraves National Forest, Arizona

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A Study of the Pollution Sources and Their Effect on the Aquatic Habitat of Eagle Creek Watershed, Apache-Sitgraves National Forest, Arizona

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Table of Contents

	Page
Table of Contents	1
List of Tables	ii
List of Figures	iii
Acknowledgements	v
Introduction	1
General Sampling Procedures	14
Habitat Quality Procedures	14
Physico-chemical	14
Biological Indicators	17
Taxonomy of Chitty Creek Trout Procedures	20
Habitat Quality Results	26
Physico-chemical	26
Biological Indicators	46
Taxonomy of Chitty Creek Trout Results	65
Conclusions	73
Literature Cited	76
Appendix	82

List of Tables

Table		Page
1	Relative abundance and biomass of macroinvertebrates from three areas on the Eagle Creek Watershed.	49
2	Catch of each species relative to habitat type and season	58
3	Mean condition factors of each fish species for each sample period	64
4	Student's t-test values for trout populations comparisons.	69
5	Comparison of Chitty Creek trout with other trout for the degree of non-overlap (C.D.) in character ratios.	71

List of Figures

Figure		Page
1	Map of study area on Eagle Creek Watershed illustrating sampling locations and prominent geographic features.	2
2	Temperature data from thermograph on Chitty Creek	27
3	Temperature date from Eagle Creek at Four Drag Ranch.	27
4	Monthly water quality ¼ mile below Honeymoon Campground.	28
5	Monthly water quality above 4-Drag Ranch on Eagle Creek	29
6	Water quality on Eagle Creek at Dry Prong . .	30
7	Water quality in Dry Prong Creek.	31
8	Water quality on Chitty Creek below falls . .	32
9	Water quality on Chitty Creek above falls . .	33
10	Relationship between conductivity and Total Dissolved Solids in Eagle Creek	40
11	Bottom composition before and after summer rain season	42
12	Bottom composition of East Eagle Creek above Dry Prong Creek (DP).	43
13	Abundance and relative biomass of macroinvertebrates from pools and riffles in Eagle Creek Watershed	47
14	Relative abundance of fish species in Eagle Creek	53
15	Sampling period when each native fish species was most abundant	54
16	Relative abundance of native fish in catch during April, August, and February.	55

List of Figures (Cont'd)

Figure		Page
17	Relative abundance of each species in three habitats.	57
18	Length frequency histograms of Agosia chrysogaster in 3 mm intervals.	59
19	Length frequency histograms of Rhinichthys osculus in 3 mm intervals	60
20	Length frequency histograms for Gila robusta in 3 mm intervals	61
21	Length frequency histograms of Pantosteus clarki in 3 mm intervals.	62
22	Length frequency histograms of Catostomus insignis in 3 mm intervals.	63
23	Plot of the mean discriminant scores (group centroids) resulting from comparison of Chitty Creek trout (Ch) with S. apache, S. gilae, and hatchery Rainbow trout (HRT).	67

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Dr. Douglas Jester of New Mexico State University was most generous with his time and provided Gila trout specimens for our examination. Mack and Stella Hughes deserve a very special thanks for providing meals, lodging, and horses for the field crews.

Introduction

The Eagle Creek Watershed is located on the Apache Sitgraves National Forest at the western edge of Greenlee County, Arizona. Eagle Creek drains a large watershed that originates along the Mogollon Rim and terminates some 40 miles south of the Rim at the Gila River approximately 15 mi west of the town of Morenci, Arizona (Figure 1). Chitty Creek flows south off the Mogollon Rim and joins Eagle Creek approximately 7 miles from its eastern origin on the Rim. Snow melt, springs, and runoff from the Mogollon Rim provide an adequate water supply to maintain permanent year round stream flow in both streams. Chitty Creek flows over bedrock for much of its mile or so length before it cascades over a 10 m high waterfall. Below the waterfall and beaver dam it is often intermittent before joining Eagle Creek. Normally, Eagle Creek is intermittent above Dry Prong Creek but flows year round from Dry Prong to 10 or 15 miles below Honeymoon Campground. Dry Prong Creek is a dry wash and only has permanent water in its lower 100 m. This 100 m is composed predominantly of shallow (< 1 m deep) unshaded pools with abundant aquatic vegetation and only a small water flow between pools.

The area along the stream in the study area could be characterized as a pine forest transition life zone (Lowe 1964) The riparian vegetation along Eagle Creek was composed of large high-canopied cottonwoods and sycamores with an

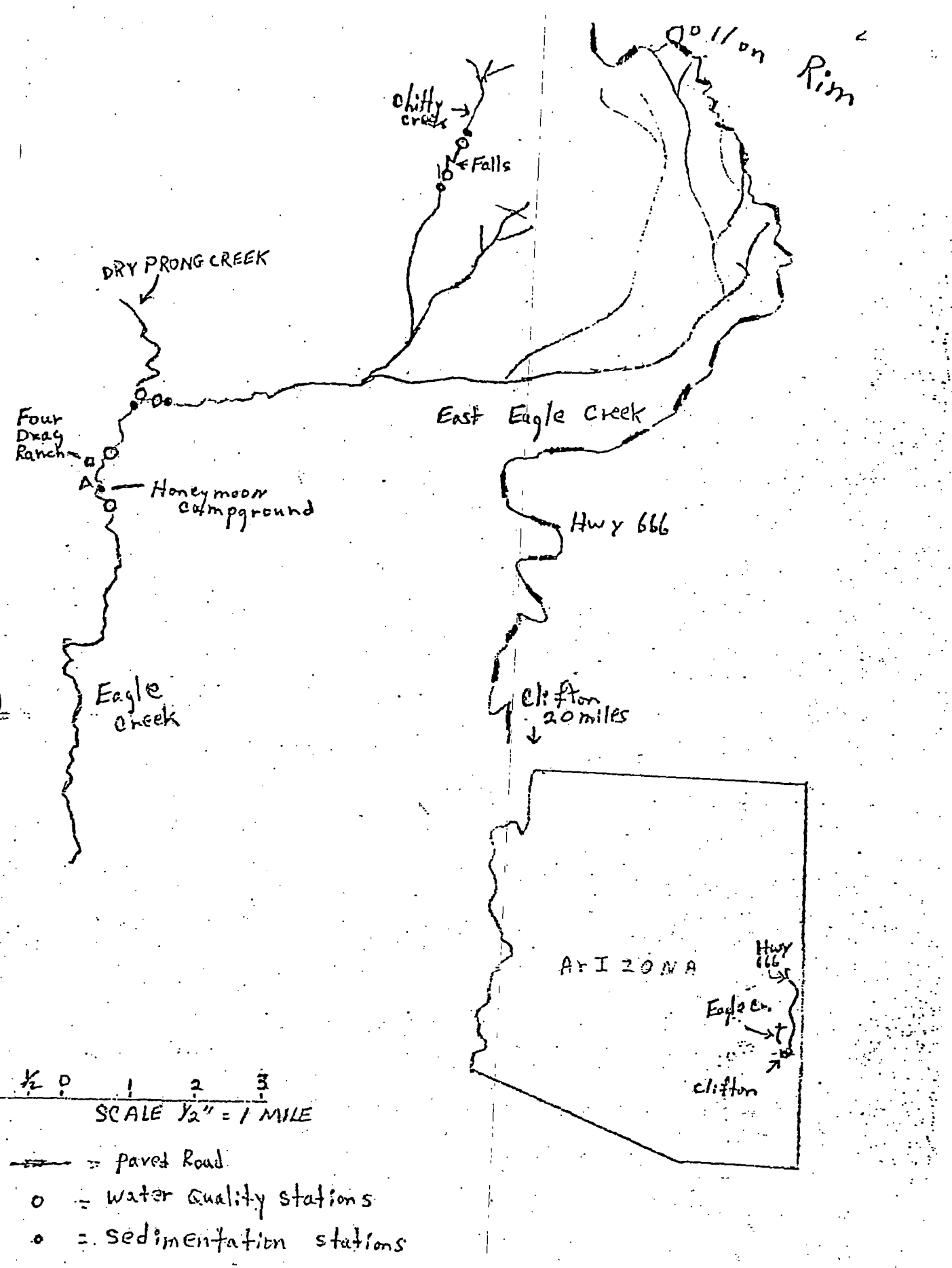


Figure 1. Map of study area on Eagle Creek Watershed illustrating sampling locations and prominent geographic features.

abundance of shrubby stands on the banks. Ponderosa pine was interspersed throughout and became most abundant along the stream and slopes at Chitty Creek. The diminutive Chitty Creek was almost completely shaded from the sun by tree canopy and the steep slopes on both sides prevented more than a few hours of direct radiation each day. Although Eagle Creek was also shaded by riparian vegetation for much of its length in the study area, there were large open areas where direct sunlight fell on the stream.

The upper area of the study on Chitty Creek was located at 7600 ft elevation. The lowest area of study at Honeymoon Campground was located at approximately 5500 ft elevation.

The area of study is used for recreation and grazing of cattle. The entire area has been subject to cattle grazing for many years. Miscellaneous observations along this watershed indicated that cattle often tended to concentrate along the stream or its slopes where adequate forage and water are always located. Although cattle are known to be able to contribute pollution concentrations of fecal coliform and fecal streptococcus bacteria to mountain streams (Kunkle and Meiman 1967), I am not familiar with any such data on the Eagle Creek watershed. Possibly at times they could affect aquatic habitat by (1) contributing significant amounts of nitrates, phosphates, and other plant nutrients to the stream (2) denuding topsoil of plant cover and hastening erosion (3) collapsing

streambanks, and (4) destroying riparian vegetation and stream cover by overgrazing.

Recreational uses of Eagle Creek Watershed include (1) overnight camping at Honeymoon (2) hiking along the many marked trails in the area (3) stream wading and swimming, predominantly during national holidays (4) fishing for stocked catchable-sized rainbow trout in Eagle Creek or native trout (?) in Chitty Creek, and (5) hunting for mule deer, turkey, squirrel and bear. Access is by gravel road from Highway 666 to Honeymoon Campground. Above the campground, all travel up the stream is by hiking, horseback, or on a recently made 4-wheel jeep trail that extends up Eagle Creek, over the Mogollon Rim, and into the Black River Watershed. Eagle Creek flows off the Rim and through the area creating a diverse habitat for vegetation and aquatic and terrestrial wildlife. The natural, free flowing, surface waters found in the Eagle Creek Watershed have all but disappeared from southern Arizona. A visit to the large relatively undisturbed Eagle Creek Watershed represents a unique contact with a natural stream in a desert riparian setting.

Previous Studies

Besides miscellaneous field collecting of native fishes for taxonomy and geographical distribution (Minckley 1973, Miller and Lowe 1964), study of the aquatic habitat of Eagle Creek has been largely ignored. A priori, one wouldn't think

that the habitat had been degraded to any great extent in recent years because native fishes that were present in the 1950's and early 1960's still remain in 1976.

Objectives

This study sought to provide a first step toward a better understanding of the aquatic habitat in Eagle Creek Watershed. Prime concern in any water-based area, especially a recreation area, is water quality and the effect of various point and non-point sources of pollution on the quality of water. In the Eagle Creek Watershed several pollution problems were anticipated (1) solar radiation increasing stream temperature (non-point) (2) siltation (non-point) (3) human-animal organic nutrient enrichment (point). Because the quality of water in Eagle and Chitty Creeks was unknown and sources of pollution were mostly speculative due to lack of previous studies, this study investigated such questions as (1) what are the physical, chemical, and biological characteristics of the stream system (2) what are the relationships between season of the year and the physical, chemical, and biological factors (3) what are the potential sources of non-point pollution in this system, what is the magnitude of their effect, and which seem to pose the greatest problems for the future wellbeing of the stream habitat.

The objectives of the habitat quality investigations were to:

1. Determine the present habitat quality by investigating several pertinent physical, chemical, and biological characteristics of Eagle and Chitty Creeks,
2. Identify trends in water quality parameters throughout the study area,
3. Sample the stream habitat in such a manner that potential sources of non-point pollution can be identified and evaluated as to their effect on stream quality,
4. Determine the suitability of these waters for a cold water fishery.

The study also investigated the taxonomic status of a trout population in Chitty Creek. Since the biological uniqueness or rarity of a life form is an important component of present decision making by land managers in this country, it is important to determine the status of these fish. Only after this is done can the population and their restricted habitat be placed into proper perspective within any management plan involving the Eagle Creek Watershed.

Habitat Quality Investigations

Physico-chemical monitoring involved the determination of amount of fine bottom sediments, stream temperature and levels of dissolved oxygen, pH, amount of total dissolved solids, and concentrations of ortho-phosphates (PO_4) and nitrate nitrogen (NO_3-N). These factors were chosen as indicators of the physical habitat and water quality conditions of the stream.

Substrate is one of the most important factors effecting the characteristics of a benthic macroinvertebrate community (Hynes 1972). It is also important in the reproductive ecology and survival of any fish species that uses the bottom for egg deposition, and all species in Eagle Creek fall into this group. Increased streambed siltation has deleterious effects on habitat that can effect both stream insects and fish (Hynes 1972, Peters 1962). In this study, a synoptic survey was made of streambed composition to determine present substrate composition of sand and silt and also to locate possible non-point sources of sedimentation.

Stream temperature and dissolved oxygen are intimately related to any life form in the stream. In any stream in southern Arizona it is important to determine the thermal characteristics of the system and to locate areas where increased summer solar radiation could cause problems. This information is imperative to evaluate the proposed development of Eagle Creek as a year round trout fishery. Oxygen rarely becomes a problem in natural streams except in polluted or very warm slow streams with dense aquatic vegetation or in autumn when leaves fall into standing pools.

The level of pH is of little concern to fisheries workers except at the extremes of its range (<4.0 or >9.5, Jones 1964). It is an indication of the watershed soil characteristics and its variability throughout the year is linked to the buffering

capacity (principally bicarbonates) of the waters. Most natural waters have pH values which lie between 6 and 9 (Stumm and Morgan 1970) although desert waters tend to be more alkaline (7.2 to 9, Deacon and Minckley 1973). In the light of recent studies on stocked trout mortality due to pH shock (Ziebell, personal communication), it is important to determine if this could be a source of stocking mortality in the Eagle Creek trout fishery.

The amount of total dissolved solids can cause some freshwater animals to become eliminated (Beadle 1957). There is also evidence that TDS affects temperature tolerance in some fishes (Allanson, Ernst and Noble 1962). Normally TDS isn't a problem in the mountain regions of the intermountain west (Cole 1968) but it is recommended that TDS be included in evaluation of fishery waters (Nemerow 1974).

The addition of organic nutrients, particularly nitrogen and phosphorus, to recreational waters is important to monitor because excesses can cause an increase in algae and aquatic plant nuisance. Most often they are found in limited amounts in natural waters (Keeney 1972). Certainly these are important necessary ingredients of a healthy stream system but if present in excess amounts can deleteriously effect water-quality and aesthetic enjoyment (Hall and Sproul 1971). So, it is important to determine what levels are present, if they ever become high enough to cause excessive plant growth, and are there

locations along the stream that contribute pollution quantities. Ortho-phosphate (PO_4) and nitrate nitrogen (NO_3-N) were monitored since these are readily used by plants. Inorganic nitrogen in streams is usually small in quantity for it is quickly oxidized to the nitrate form which is then used by plants. Phosphorus exists in streams in inorganic ortho-phosphate or in complex phosphate compounds but 70 to 90% of the total phosphorus from sewage effluents is in the ortho-phosphate form (Committee Report - AWWA 1970).

Biological indicators of habitat quality chosen for study were (1) macroinvertebrate diversity, abundance, and biomass, and (2) native fish abundance, size, composition and condition. The diversity of benthic macroinvertebrates has been used many times to measure the general habitat quality and effect of induced stress on a community of macroinvertebrates (literature review in Weber 1973). Their use is based on the well demonstrated phenomenon that most natural undisturbed communities are represented by many species but no single species dominates numerically. Many forms of stress (organic pollution, sedimentation, etc.) tend to reduce diversity by making the environment unsuitable for some species or causing changes in the competitive balance between species. Macroinvertebrate biomass (weight of organisms per unit area) is also a useful quantitative estimate of standing crop. The standing crop and production of stream invertebrates is quite important

to the six species of native fish in these streams since all information indicates they all rely on them for food (Minckley 1973 and personal observations of stomachs).

The wellbeing of an aquatic habitat is reflected in the wellbeing of the fish populations. These were sampled from different stream habitats and their relative occurrence in each habitat and a general idea of numerical abundance was determined. Also, the relative plumpness of each species was determined using the commonly accepted condition coefficient (K) (Lagler 1956, Everhart, Eipper and Youngs 1975). The larger the coefficient the heavier the fish for a given length. The coefficient of condition is a convenient method for comparing the relative wellbeing of several fish populations or one population through the vicissitudes of time and/or habitat alteration.

Chitty Creek Trout Taxonomy

The historical distribution of Arizona's native trout was reviewed by Miller (1972). After examining trout specimens from all major river drainages in Arizona, he concluded that the trout identified as Gila trout (Salmo gilae (Miller 1950) occupied the headwaters of the Gila River drainage of eastern Arizona and New Mexico while the Arizona Native trout (Salmo apache) occupied headwaters of the Little Colorado and Salt Rivers. Although trout from Eagle Creek were collected and examined before (Mulch and Gamble 1954, Miller and Lowe 1964), these examinations ended with the allusion to a "pure

strain". Years later, based on specimens from Eagle Creek, not Chitty Creek, Minckley (1973) believed the trout population extinct or indistinguishable from introduced rainbow trout. From distributional relationships of native chubs of the genus Gila and the two Arizona trouts (Salmo apache - Arizona Native trout and Salmo gilae - Gila trout), he hypothesized that the "pure strain" of trout in Eagle Creek was probably S. gilae.

Rainbow trout were introduced into Eagle Creek many years ago as part of a regional stocking program. Presently, 500 catchable sized fish are stocked each Easter in Eagle Creek at Honeymoon Campground for the put and take fishery. Some of these fish do over-summer in Eagle Creek above Honeymoon Campground. Examination of fishermen's catches of trout in Eagle Creek indicate that the native trout population that once inhabited Eagle Creek is probably extirpated as Minckley (1973) surmised.

High on the Mogollon Rim and separated from East Eagle Creek by an impressive 10 m waterfall and 4 miles or more of intermittent water flow most of the year is Chitty Creek. Accessible only by horseback or hiking trail from Strayhorse Camp and Eagle Creek, this small creek lies in a remote steep-walled canyon at the headwaters of Eagle Creek. Any population of fish above the falls is separated from contact with downstream fish. Only speckled dace (Rhynichthys osculus)

and a trout population inhabit upper Chitty Creek. Whether man at some time in the past successfully introduced hatchery rainbow trout into Chitty Creek above the falls is not known. I would speculate that a successful introduction would seem unlikely based on (1) the inaccessibility of the stream and difficulty of transporting fish over the rough terrain (2) the small size of the stream and low diversity of habitats, and (3) the extreme rigor of Chitty Creek. These factors create a high probability that an introduced fish would find all suitable habitats occupied and would be displaced downstream over the falls. If a successful introduction of rainbow trout was made into upper Chitty Creek, hybridization between the two allopatric trout populations would surely occur because there could have been no selection for reproductive isolating mechanisms, i.e., the test of sympatry (Mayr 1974). The resulting population should resemble hatchery fish in many of its characteristics. Hybridization would not indicate anything about previous genetic divergence in allopatry or about the long term outcome of natural selection acting on the resultant phenotypes of genetic exchange between the two allopatrically evolved forms.

Since the Chitty Creek population is another allopatric population of western trouts, the main criteria of the biological species concept, i.e., reproductive isolating mechanisms in sympatry (Mayr 1974) cannot be applied to the determination

of systematic status. Instead one must rely on geographical relationships and the presence or absence of differences that have evolved in allopatry (Mayr, Linsky, Usinger 1953). In practice, the degree of morphological difference is most used to decide questions of this nature although there is disagreeemtn among taxonomists as to the required amount of difference between full species and subspecies. The present study sought to examine this complex problem by examining the morphological differences between fish from upper Chitty Creek and fish from (1) Rainbow trout hatchery stock from the Alchesay Federal Hatchery at Whiteriver, Arizona (2) Native Arizona trout from headwaters of Big Bonito Creek, and (3) Gila grout from Main Diamond Creek, New Mexico. The hatchery rainbow trout were provided by the Alchesay Federal Fish Hatchery. This stock has been used for many years to plant waters in this region and it was this stock of trout that was introduced into lower Eagle Creek years ago. Trout from upper Big Bonito Creek, which originates on the south side of Baldy Mountain in the White Mountains of Arizona were used to represent Salmo apache. They seem to be "pure" Salmo apache (Kynard, unpublished data). Specimens of Gila trout (Salmo gilae) were from the type locality of the species, i.e., Main Diamond Creek, headwaters of San Francisco River, New Mexico. Dr. Douglas Jester and Mrs. Robert David of New Mexico State University at Las Cruces kindly permitted the use of these specimens.

General Sampling Procedures

Field work began in April, 1975 and continued until February of 1976. Trips were made monthly to study the aquatic habitat on Eagle and Chitty Creeks. Actual dates of field trips were April 25-27, May 28-30, June 18-24, July 13-26, August 29-30, September 18-21, October 24-26, November 21-23, December 18-22, and February 12-17.

Sampling in the Honeymoon Campground area was done from a University of Arizona vehicle. Sampling of any type that was done above Four Drag Ranch at Dry Prong or Chitty Creek was conducted from horseback with a minimum amount of supporting gear. Horses, tack, and pack gear were rented to the project by longtime residents of the area, Mack and Stella Hughes, who lived 7 mi below Four Drag Ranch on Eagle Creek. They also provided housing and meals at reasonable cost to the project for Mr. Will Hayes (technician) and his occasional assistants.

Habitat Quality Procedures

Physico-chemical

Water quality was taken at six stations in three sections of the watershed (1) Chitty Creek (2) Eagle Creek at Dry Prong, and (3) Eagle Creek at Honeymoon Campground. Within each of these three sections, sampling was further subdivided into sampling (1) Chitty Creek above the falls and below falls at the old beaver pond (2) Eagle Creek 50 m above Dry Prong and

in Dry Prong a few meters before it joined Eagle Creek, and (3) Eagle Creek 50 m above Four Drag Ranch and ¼ mile below Honeymoon Campground (Figure 1). At each station the pH, temperature and dissolved oxygen were determined immediately and time of day was recorded. Stream temperature was taken at the surface with a standard centigrade field thermometer. Dissolved oxygen was determined in the field, using procedures outlined in Hach Chemical Corporation's Methods Manual (1971), and their Hach DR-EL engineer's laboratory. An Analytical Measurements Model 707B pH meter was used for pH determination. At each station a 250 ml water sample was placed in a bottle, sterilized with 5 ml chloroform, and transported to the University of Arizona for analysis of nitrate nitrogen (NO_3-N), phosphates (PO_4), and conductivity. Nitrates and phosphates were analysed with the Hach DR-EL laboratory with the newly added low range nitrate and phosphate scales. Conductivity was determined with a conductivity meter. Several water samples were also analysed for total dissolved solids according to Standard Methods (1971) so that conductivity could be translated into amount of TDS.

A constant monitoring of stream temperature was attempted by installing two 30 day Ryan thermographs on the watershed. One was placed on Chitty Creek above the falls and the other ¼ mile above the Four Drag Ranch on Eagle Creek. When the thermograph at Four Drag Ranch malfunctioned and a replacement

could not be found, daily stream temperatures were collected at 0800-0900 hrs, 1100-1200 hrs, and 1700-1800 hrs from July 27 to August 21 by Mrs. Nichols at the Four Drag Ranch with a standard centigrade field thermometer.

Eagle Creek was sampled for streambed composition in April and September of 1975. Chitty Creek was sampled in July and September of 1975. Five sediment sampling stations were established on the watershed (Figure 1). These were categorized as:

Station 1) Ten samples 50 m below Honeymoon Campground at downstream end of raceway

Station 2) Five samples 100 m downstream of Dry Prong on Eagle Creek

Station 3) Five samples 100 m upstream of Dry Prong on Eagle Creek

Station 4) Five samples above falls in raceway on Chitty Creek

Station 5) Five samples below falls and above beaver pond in area of small pools on Chitty Creek

Bottom samples were taken with a cylindrical bottom corer similar to the one developed by McNeil and Ahnel (1964). This same bottom sampler was used in sampling three streams in the White Mountains of Arizona for bottom composition (Harper 1976). It sampled a 85 mm x 85 mm cylinder of substrate. After this quantity of material was excavated it was placed in plastic

bags, and transferred to the University of Arizona. Each sample was separated into size components by washing the sample through a series of standard sieves with openings of 32 mm, 16 mm, 8 mm, 4 mm, 0.85 mm, and .40 mm. The volume of each component was determined directly by displacement of water and cms converted to the percentage of the total sample. The material that passed through the 0.40 mm sieve was collected in a graduated cylinder and the volume was taken after allowing 10 minutes to settle. Substrate size was classified after Hynes (1972).

Biological Indicators

The benthic insect population in the Eagle Creek Watershed was sampled June 18, 19 and 21, 1975. Sampling was done in three areas of the watershed (1) Eagle Creek a short distance above Four Drag Ranch (2) Eagle Creek at Dry Prong, and (3) Chitty Creek above the falls. Three pools and three riffles were sampled at each area to get a good representation of the occurrence and general abundance of the various insects. All samples were taken with a Surber sampler with side wings (Wildco Instruments) which sampled one ft^2 of bottom. Six samples (3-pool and 3-riffle) from each of the three regions of the watershed was thought to be sufficient to sample the main forms present for determination of the summer diversity (Hynes 1972). Also, these samples gave an indication of the abundance and biomass of this important source of food for the stream fish.

After collection, macroinvertebrate samples were placed in zip-lock bags, preserved in ethyl alcohol, and transferred to the University of Arizona. After separation of macroinvertebrates from sediments and debris by the sugar flotation method, benthic insects were identified to family using Usinger (1966). All macroinvertebrates were enumerated and the mean wet weight of an individual of each family was determined by allowing all members of each group to air dry for five minutes on a paper napkin. After this period, total weight of each group was determined using a Mettler Balance Model H-16. This permitted the calculation of relative biomass figures for the various insect groups.

Benthic insect diversity indices for the three areas of the watershed were calculated using the Shannon-Weiner information theory function for the analysis (Pielou 1966, Weber 1973). Both components of species diversity were calculated, i.e., richness of species (H or $\bar{d}$) and evenness of distribution of individuals among the species (E). The Shannon-Weiner formula based on information theory is

$$H = \sum_{i=1}^{s} Pi \ (\log_2 pi)$$

where H or $\bar{d}$ is the information content of sample (mean diversity) s is the number of species (or families) and pi is the proportion of the total sample belonging to the inth species.

Native fish were collected from Eagle Creek Watershed in spring (April 25, 1975), late summer (August 29, 1975) and winter (February 13, 1976). Two areas of the watershed were sampled for fish, i.e., Eagle Creek ½ mi above Four Drag Ranch and Dry Prong Creek. In Eagle Creek, two habitats (riffle and raceway) were sampled for relative abundance of each species. The Dry Prong habitat was comprised of slowly draining pools with abundant dense vegetation (Potamogeton sp and Chara sp). Sampling was done with a backpack battery powered electrical shocker and seine blocks across the stream. In Dry Prong's dense vegetation, sampling was done with a heavily weighted 10 ft ¼ inch mesh common sense minnow seine and electroshocker. After sampling, fish were preserved in 10% formalin and transported to the University of Arizona. In the laboratory each fish was identified to species. Its total length was determined to the nearest mm and wet weight was determined to the nearest 0.1 gram on a Mettler top loading electronic balance (Model P-160). Total lengths were later used to determine length frequency histograms for each species.

Condition coefficient (K) was calculated using the formula

$$K = W/L^3$$

where K is the coefficient of condition, W is the weight, and L is fish length (Lagler, 1956). Mean condition factors were calculated for each species at the three seasons.

Several of the algae and aquatic vascular plants were also determined in the Eagle Creek Watershed (Appendix 1). During summer and fall of 1975, plants were collected in Eagle Creek and Dry Prong and were identified by Dr. Robert Hoshaw, Botanist in the Dept. of Biological Sciences, University of Arizona. It was hoped this information on plants would add to the basic knowledge of the aquatic flora of the Eagle Creek Watershed.

Taxonomy of Chitty Creek Trout Procedures

On August 29, 1975, 36 fish were collected from Chitty Creek above the waterfall. These fish were used in all comparisons with 28 hatchery Rainbow trout (Salmo gairdneri), 15 Salmo gilae from Main Diamond Creek and 30 Salmo apache from headwaters of Big Bonito Creek.

On each fish from these four stocks, morphometric measurements or meristic counts were taken on eleven continuous morphological variables. All except snout length had been identified previously as generally diagnostic between S. apache and S. gilae and S. gairdneri by Miller (1972), and recently by David (1976), i.e., head length, position of the dorsal fin, adipose fin length, size of dorsal and anal fins, mouth size (maxillary bone length) and degree of body spotting. Color photographs and descriptions of live fish were taken in the field to use for comparison of life colors.

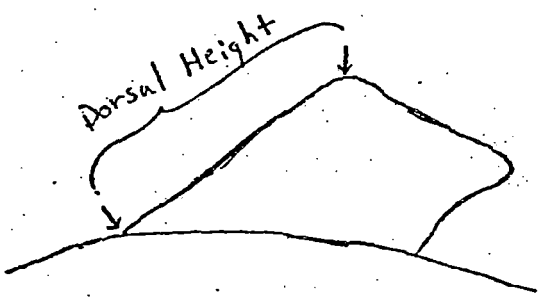
Techniques followed those of Hubbs and Lagler (1958) except as noted below in the description of characters:

1) Total length - caudal rays squeezed together and measurement of most anterior part of head to farthest tip of caudal fin

2) Predorsal length - as in Hubbs and Lagler (1958)

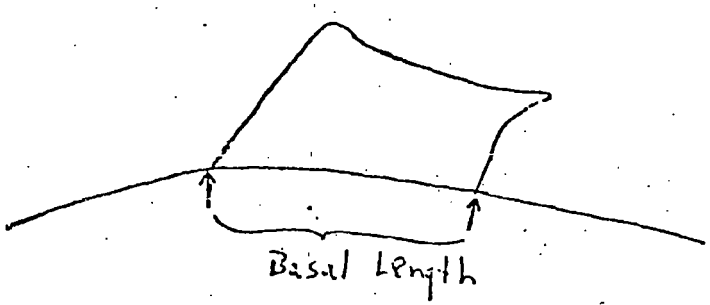
3) Anal fin, basal length - as in Hubbs and Lagler (1958)

4) Dorsal fin, height - measured on a fully extended fin, from anterior origin of the fin to the tip of the anterior lobe as viewed from the left side:

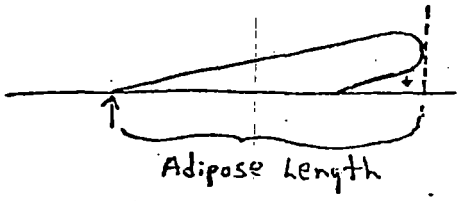


5) Dorsal fin, depressed length - measurement taken dorsally on maximally depressed fin, from anterior origin to most posterior tip

6) Dorsal fin, basal length - measured with the fin fully extended, anterior point of insertion to point of insertion



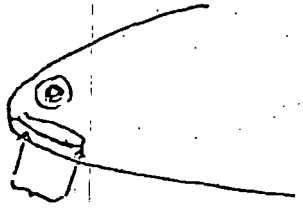
7) Adipose fin, depressed length - as viewed from the left side, the anterior point where the fin base rises above the body contour to the posterior tip of fin depressed down against the body (not on its side)



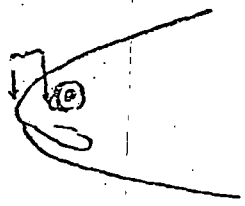
8) Head length - most anterior part of head to farthest tip of opercular membrane as viewed from left side

9) Upper jaw length - from most anterior point of premaxillary to most posterior point on maxillary bone

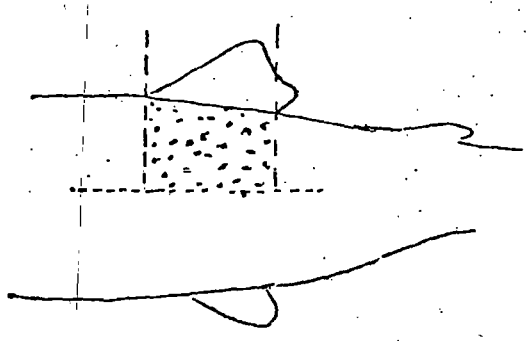
10) Maxillary length - from cleft where premaxillary articulates with maxillary bone to most posterior point on maxillary



11) Snout length - from anterior tip of snout to the most anterior edge of the orbital rim, i.e., that part of the orbital rim closest to the snout. This deviates from Hubbs and Lagler (1958). Snout lengths taken repeatedly their way were too variable due to the lack of an accurate posterior point. The present technique was chosen for its accuracy and repeatability although it is not the accepted snout length measurement.



12) Dorsal spotting - the mean number of spots resulting from three counts in the area directly beneath the basal length of the dorsal fin and extending to the lateral line. Spots touching border of lines were counted. Adjoining spots were counted as one.



Fish used in this and most taxonomic comparisons are collected at different times and are not the same size. For comparisons between populations, taxonomists usually are able to compensate for this problem by using ratios or proportions of characters to total length or another character rather than use only the linear measurements. This is because in most species that continue to grow as adults (such as fish) the proportions of the various body parts to each other often remain constant (Mayr, Lindsley, and Usinger 1953). For comparisons of fish populations, the total or standard length of each individual fish is most often used in ratios to minimize the variable factor of size. In this study all linear measurements were standardized to total length and expressed to thousandths of a mm, i.e.,

$$\text{character ratio} = \frac{\text{character length (0.000)} \times 100}{\text{total length (0.000)}}$$

The validity of making these ratio comparisons between the four trout populations was tested by comparing graphs of each population's character ratio vs size. The four populations were visually compared for change in character ratios with size.

Several analyses of the data were run at the University of Arizona Computer Center. A multivariate analysis of the data was performed using the discriminant analysis Subprogram DISCRIMINANT of Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner, and Brent 1975). This

program examined Chitty trout vs hatchery Rainbow trout, Chitty trout vs Gila trout, and Chitty trout vs Arizona trout, for statistically significant differences between them for the eleven characters. To evaluate the effects of difference in size between the populations on the results a second discriminant analysis was performed that used twelve variables, i.e., total length of each fish was included.

These tests gave weight to the variables and mathematically combined the discriminating variables linearly so that the two groups were forced to be as statistically distinct as possible. The SPSS analysis generated several kinds of information that aided in determining the variables that contributed most to discrimination, i.e., t-tests of variable means between groups Standardized Discriminant Function coefficients (to evaluate most important variables) and mean group discriminant centrads (the mean discriminant function of the group that is used in scatter groups to depict visually the mathematical location of the various groups). All variables were considered important, so all were used in the calculation of the discriminate function. SPSS also tested the validity of the discriminant function it generated by attempting to reclassify each case into its original group. Eigen values and Wilks Lamda also aided in evaluating the degree of separation between the two groups.

To further delineate differences between the populations for the characters, the SPSS Subprogram t-test was run to compare the populations means for each character ratio. This analysis permitted a check of the discriminant analysis results and put the character comparisons into another form that is more useable by field biologists who come into contact with these problems on a routine basis.

Habitat Quality Results

Physico-chemical

The results of the Ryan thermograph stream temperature monitoring is presented in Figures 2 and 3. The Ryans malfunctioned (would not run properly) from the beginning and replacements could not be obtained from the Forest Service. The small amount of data from the thermograph on Eagle Creek above Four Drag Ranch appeared worthless since the July 26 to 31 thermograph data on highest daily stream temperatures didn't agree at all with the highest temperatures for these dates that were recorded by Mrs. Nichols at Four Drag Ranch. Her daily high temperatures of 23°C to 25°C agreed quite well with the highs recorded by Mr. Will Hayes, technician. The stream temperatures and the times they were taken by Mr. Hayes on his monthly trips is presented for each station in Figures 4-9. There are several gaps in the data that resulted when thermometers were lost or were broken by horses but the general variation of water temperature at the different stations leads

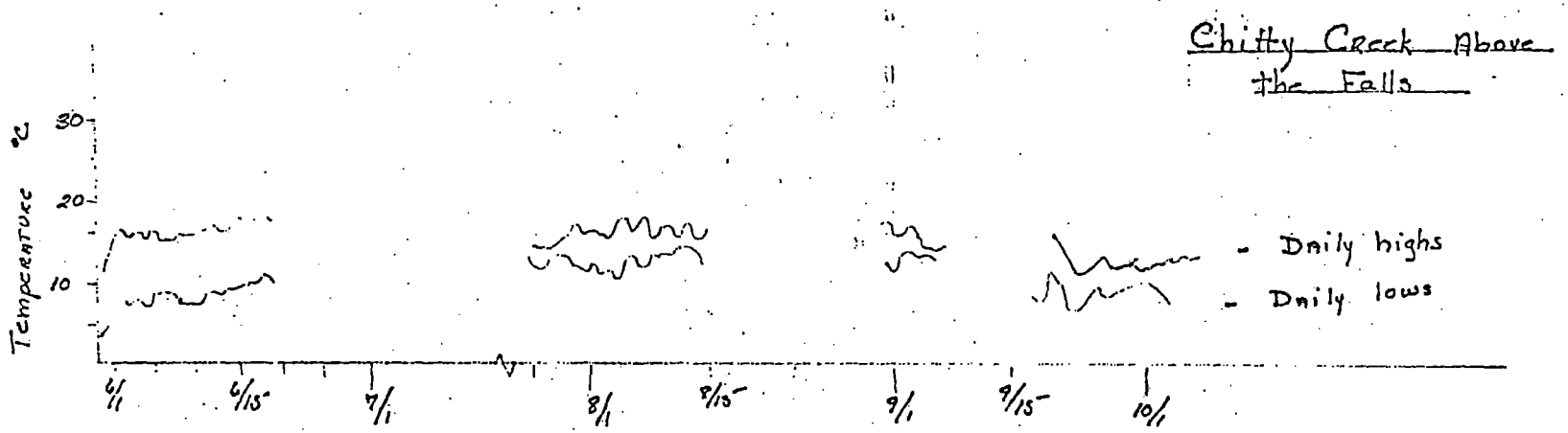


Figure 2. Temperature data from thermograph on Chitty Creek.

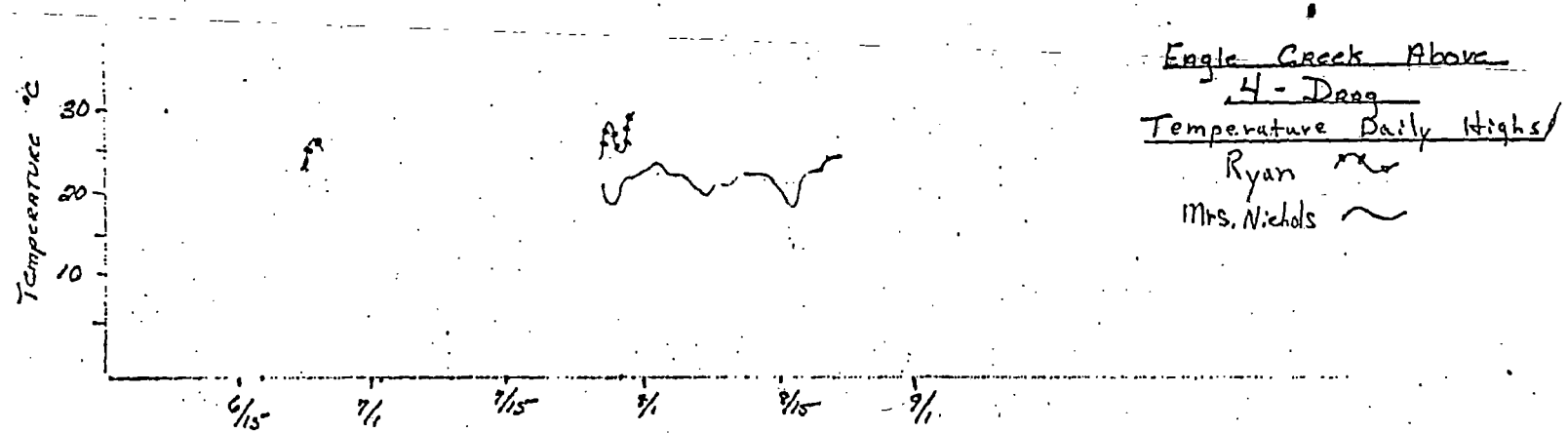


Figure 3. Temperature data from Eagle Creek at Four Drag Ranch.

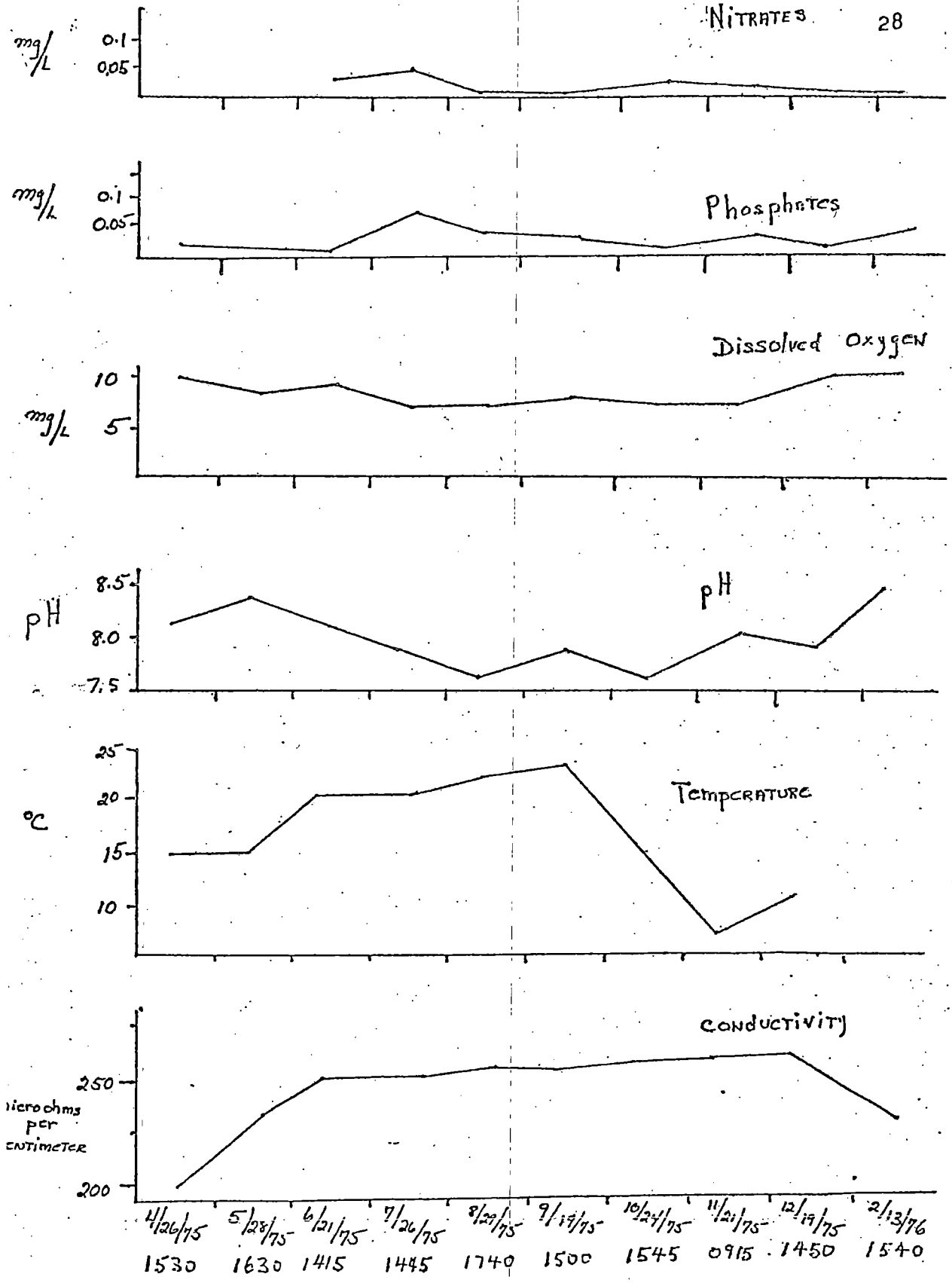


Figure 4. Monthly water quality ¼ mile below Honeymoon Campground. Time below sample dates are times of temperature determination.

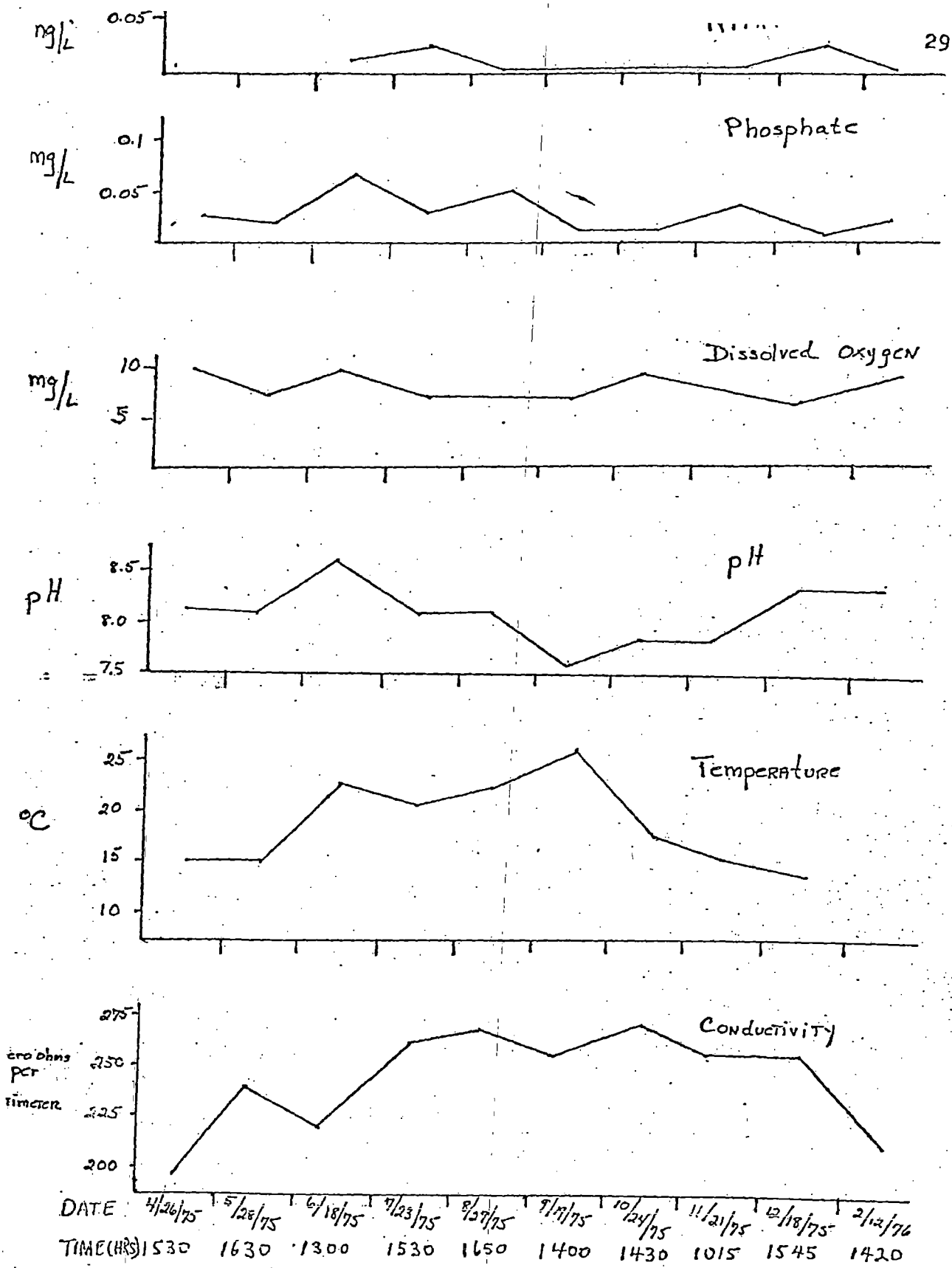


Figure 5. Monthly water quality above 4-Drag Ranch on Eagle Creek. Time below sample dates are times of temperature determination.

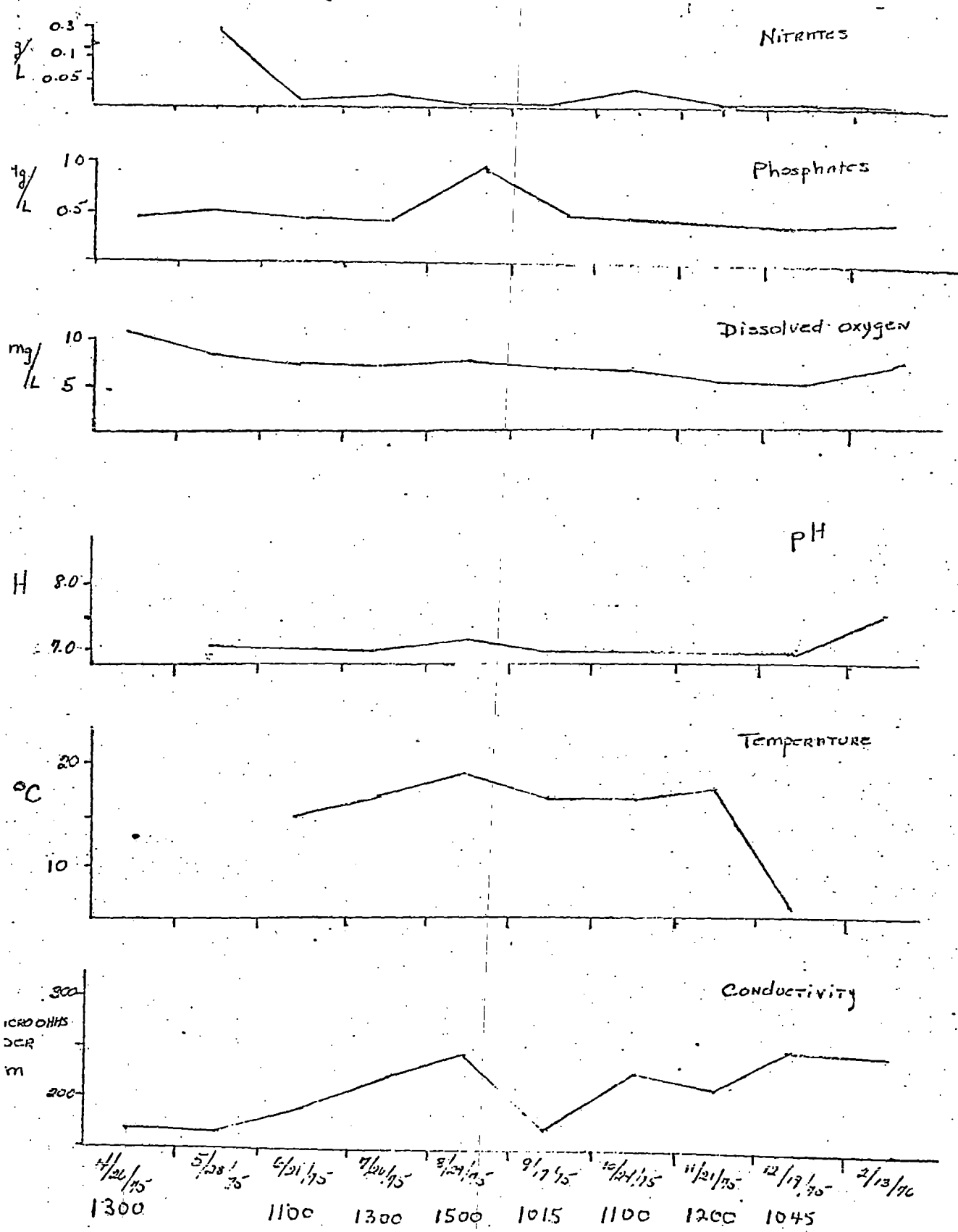


Figure 6. Water quality on Eagle Creek at Dry Prong. Time below sample dates are times of temperature determination.

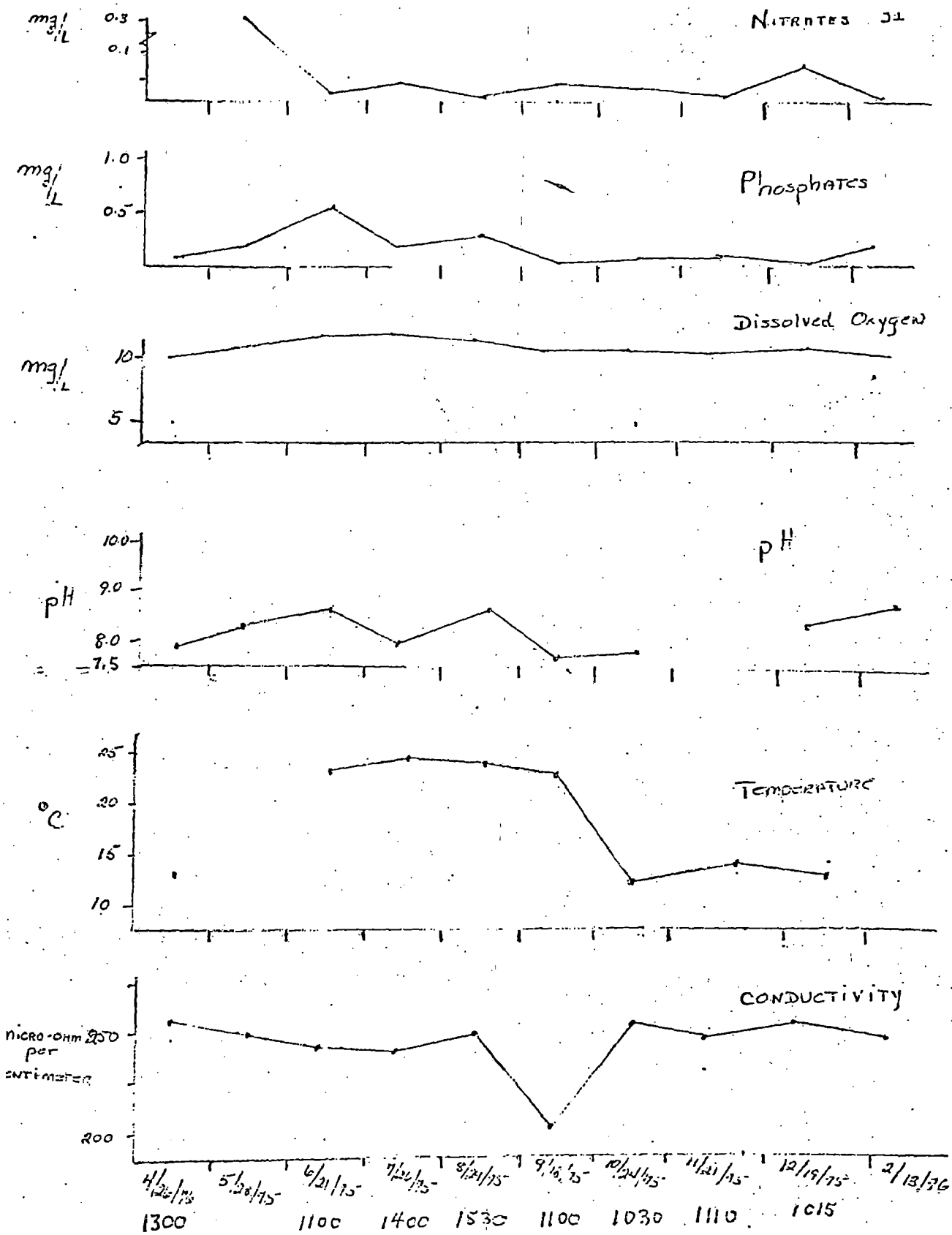


Figure 7. Water quality in Dry Prong Creek. Time below sample dates are times of temperature determination.

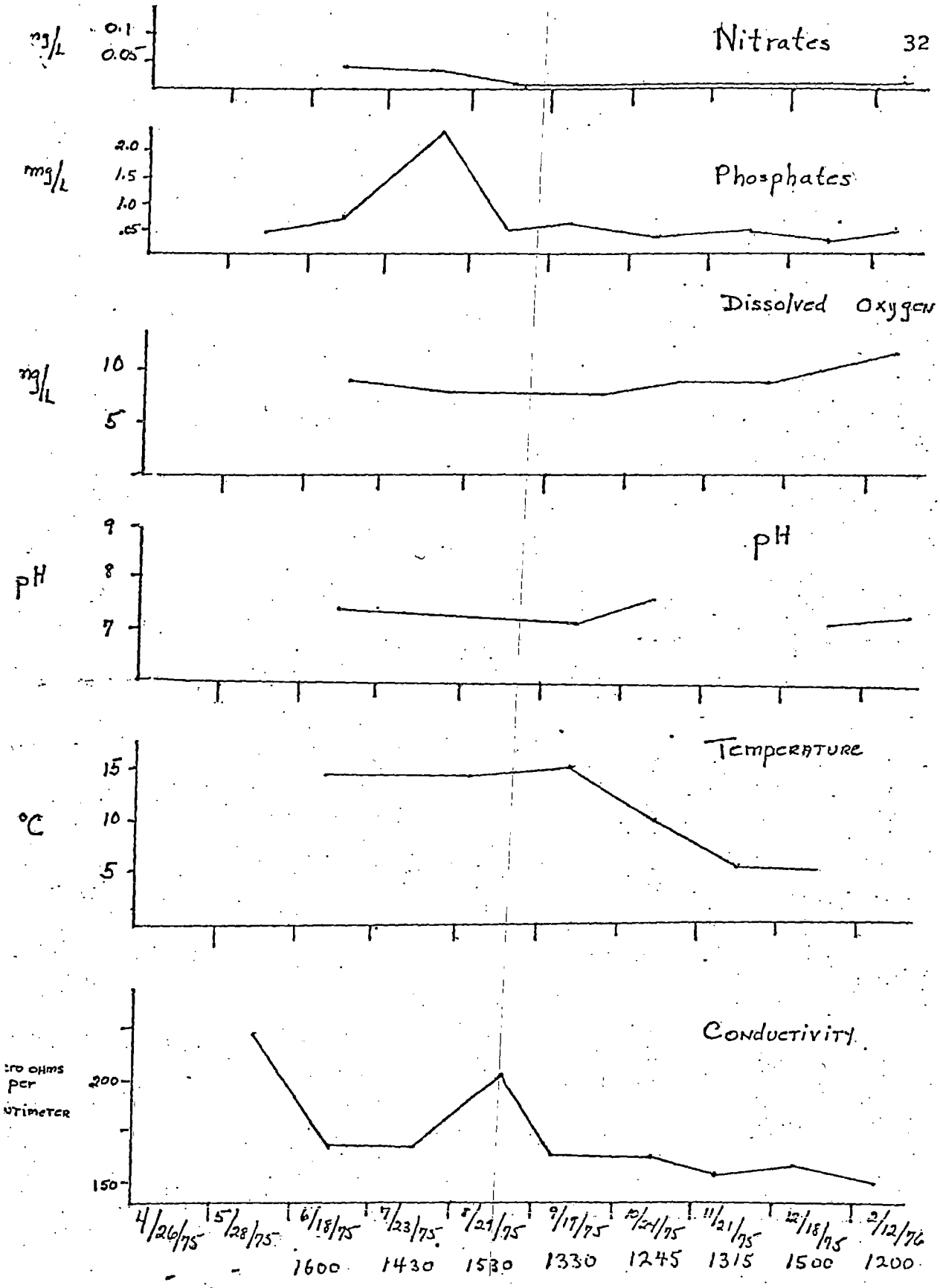


Figure 8. Water quality on Chitty Creek below falls. Numbers below sample dates are times of temperature determination.

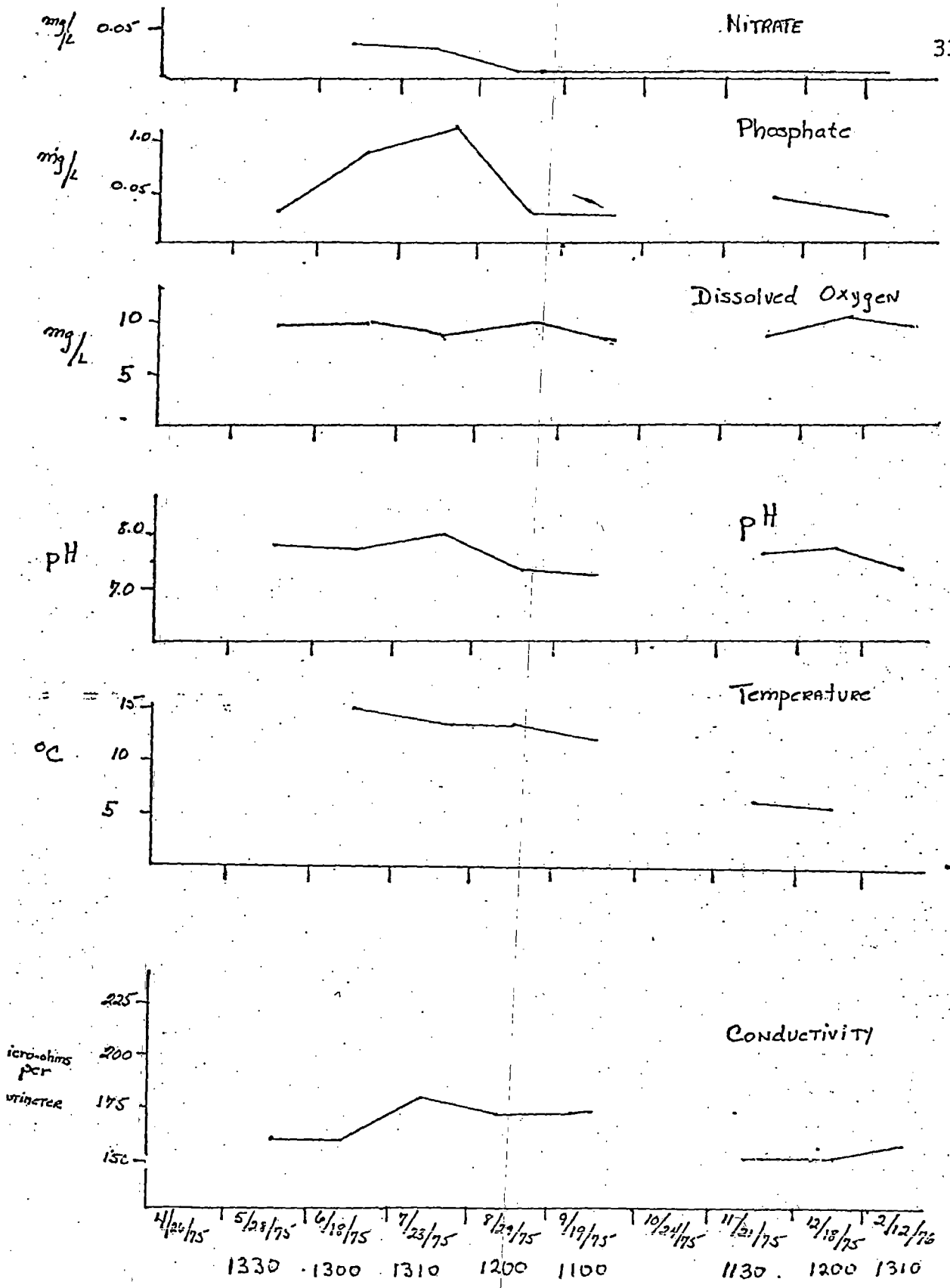


Figure 9. Water quality on Chitty Creek above falls. Numbers below sample dates are times of temperature determination.

to the general conclusions that (1) temperatures in Chitty Creek were the coolest and well within accepted temperature limits of trout with daily minimum temperatures in summer of 10°C to 14°C and daily maximums of 17°C to 18°C (Figure 2); (2) Eagle Creek at Dry Prong seemed to have amenable temperatures for trout but Dry Prong Creek added water to Eagle Creek that was much warmer than Eagle Creek (sometimes by 10°C) and this could possibly form a hot water block for upstream movement by trout during periods of low flow in Eagle Creek; (3) the temperatures in the area around Honeymoon were too warm for trout feeding/growth and survival during summer. The mean daily high temperature at the Four Drag Ranch during July 26 to August 24 was 23.1°C. This exceeds by 3.1°C the recommended summer maximum water temperature standards for resident trout waters of the Federal Water Pollution Control Administration (USDI 1970). It exceeded their recommended standard for rearing areas by 8°C. Even though the summer of the study was unusually wet and cool (Mack Hughes, personal communication), stream temperatures on Eagle Creek below Dry Prong exceeded recommended standards for trout from the last of June into September (Figure 5). This factor alone would seem to preclude Eagle Creek from ever having anything but a put and take Rainbow trout fishery.

As has been correctly pointed out by Patton (1973), water temperature is probably the most important factor that affects

the physiology of fish. At the summer water temperatures in Eagle Creek below Dry Prong, the Arizona trout (Salmo apache) would cease feeding and eventually most would die (Alcorn 1976). In summer the water temperatures in Eagle Creek above Dry Prong were 20°C or less. The stream warmed drastically in the short distance to Four Drag Ranch where highs exceeded 20°C each day. This warming was probably due to several factors, i.e., (1) above Dry Prong, Eagle Creek was intermittent in flow, (2) Dry Prong contributed very warm water although the amount added was not determined, (3) below Dry Prong there was surface flow and in many areas the stream received direct radiation.

The levels of dissolved oxygen in Chitty and Eagle Creeks during the day were always above 5-6 mg/l, which is considered minimum for trout wellbeing (McKee and Wolf 1963). This was expected because, although there were dense areas of aquatic vegetation that might cause low D.O. problems at night or early morning, the steep gradient of Eagle Creek insured an abundance of riffles above Honeymoon Campground. The high dissolved oxygen levels found during the day in Dry Prong were undoubtedly caused by the abundant aquatic vegetation. During the night there may be oxygen problems in Dry Prong. Its low rate of flow, lack of riffles for aeration, dense vegetation, and warm temperatures all could combine to cause a low night-time oxygen level that might be critical to fish survival.

The pH levels found in Eagle and Chitty Creeks were within the acceptable range of pH for general fish wellbeing recommended by McKee and Wolf (1963) and the State of Arizona (Nemerow 1974). They were also of the magnitude found in other western desert streams (Motschall 1976, Deacon and Minckley 1973, Cole 1969). Motschall (1976) found that the pH in Sabino and Bear Creeks of the Santa Catalina Mountains was neutral and varied little during the year. The pH does vary from upstream to downstream on Eagle Creek. At Chitty Creek the pH ranged from 7.5 to 8, on Eagle Creek above Dry Prong the pH varied little from 7.0 and at Honeymoon the range was from 7.6 to 8.5. This probably reflected the effects of groundwater additions to the system. No pollution problem with pH appeared to exist within the stream and the pH was relatively constant over many miles of stream. This constancy was probably indicative of a well buffered system and of relatively little inflow of waters containing highly alkaline or acidic components. There would also appear to be no problem of pH shock for stocked hatchery trout as these fish are transferred from hatchery water of almost neutral pH into Eagle Creek at Honeymoon where the pH in April and May is 8 to 8.5. The problem of pH shock seems to exist when the transfer is from fish in neutral pH waters to waters with a pH of 9.5 or greater.

The level of nitrate (NO_3-N) in Eagle and Chitty Creeks was low and below the generally accepted 0.3 mg/l amount associated with problem algae in streams (Mackenthun 1969) (Figures

4-9). Only once did nitrate levels rise over .1 mg/l (May sample for Eagle Creek at Dry Prong) and that was a temporary increase. No seasonal pattern of nitrate change was detected except for a possible slight increase during summer (June and July). The levels of nitrates in the Eagle Creek Watershed were usually less than .05 mg/l. This was considerably lower than the usual .4 mg/l in Sabino and Bear Creeks in the Coronado National Forest (Motschall 1976). Desert waters are usually low in nitrogen (Cole 1968) and the Eagle Creek Watershed doesn't appear to be an exception.

Hutchinson (1957) described the range of phosphorus in natural waters as .01 to .04 mg/l. Polluted waters in the United States range to .10 mg/l and in flowing waters total phosphorus should not exceed .1 mg/l in order to prevent excessive aquatic growth (Mackenthun 1969). Ortho-phosphate levels for Sabino and Bear Creek in the Coronado National Forest ranged from .02 to .06 mg/l (Sabino Cr.) and .02 to .07 mg/l (Bear Cr.) (Motschall 1976).

Ortho-phosphate levels in the Eagle Creek Watershed vary tremendously from location to location. At Chitty Creek, levels were usually .05 mg/l but during June and July (beginning of the rainy season) the level was in excess of 1 mg/l (Figure 9). Eagle Creek above Dry Prong always had .5 mg/l ortho-phosphate or greater and it increased in August to 1 mg/l (Figure 6). The plants in Dry Prong Creek evidently kept most

of the phosphate tied up because ortho-phosphate levels were much lower than in East Eagle Creek. Ortho-phosphate levels on Eagle Creek above the Four Drag Ranch and below the campground were the lowest encountered on the stream and only twice exceeded .05 mg/l. It appeared that the relatively high levels of phosphate in the upper stream areas were tied up by plants in the stream's lower courses. This is important to lower stream productivity and partially explains the reasons for the dense growth of aquatic plants in the lower stream.

The stock corrals at Dry Prong and Four Drag Ranch and the campground area were obvious potential sources of increased nutrients (nitrates and phosphates) from humans and livestock. The monthly samples on East Eagle Creek above Dry Prong and in Dry Prong and on Eagle Creek above and below the ranch and campground were taken in an attempt to determine if these were areas of organic pollution. The monthly samples did not indicate any pollution quantities of nitrates or phosphates from these sites. The relatively constant large amounts of phosphates (.5 to 1 mg/l) in the upstream waters on Eagle Creek at Dry Prong (Figure 6) were reduced to .05 mg/l or less in the two mile distance to Four Drag Ranch (Figure 5). Observations on this area of stream during various seasons indicated the lush aquatic plants that were present, even in January, were probably responsible for this dramatic decrease in phosphates. The dense growth of aquatic plants in this area would be detrimental to some aesthetic and recreational uses of the stream

by man (Mackenthun 1969), but under its present management it probably only enhances the stream plants, aquatic insects, and native fish populations.

The total dissolved solids in Eagle Creek were low for streams in southern Arizona (Figures 4-9). The relationship between conductivity and TDS in Eagle Creek is presented in Figure 10. Specific conductance was on the low side of acceptability for sustaining a good mixed fish fauna according to McKee and Wolf (1963). Hart et al (1945) reported that about 50% of the waters in the United States had specific conductivity under 270 X 10 mhos. TDS was very different for each stream area, i.e., (1) Chitty Creek was lowest (range 120 mg/l to 175 mg/l) (2) Eagle Creek at Dry Prong was intermediate with 140 mg/l to 190 mg/l (3) Dry Prong Creek was high all year at 190 mg/l or greater (4) lower Eagle Creek was highest and ranged from 150 mg/l to 190 mg/l. The variation in each area during the year was quite different also, i.e., Chitty Creek showed a gradual decline in amount of TDS from spring to winter, in Eagle Creek at Dry Prong TDS gradually increased from spring to winter, and in lower Eagle Creek TDS was lowest in late winter-early spring and increased in June and remained stable and high until December. All stations on Eagle Creek had a marked decrease in amount of TDS in the September samples (Figures 4-9).

The amount of total dissolved solids were low and no problem areas were found anywhere on the watershed. Although Dry

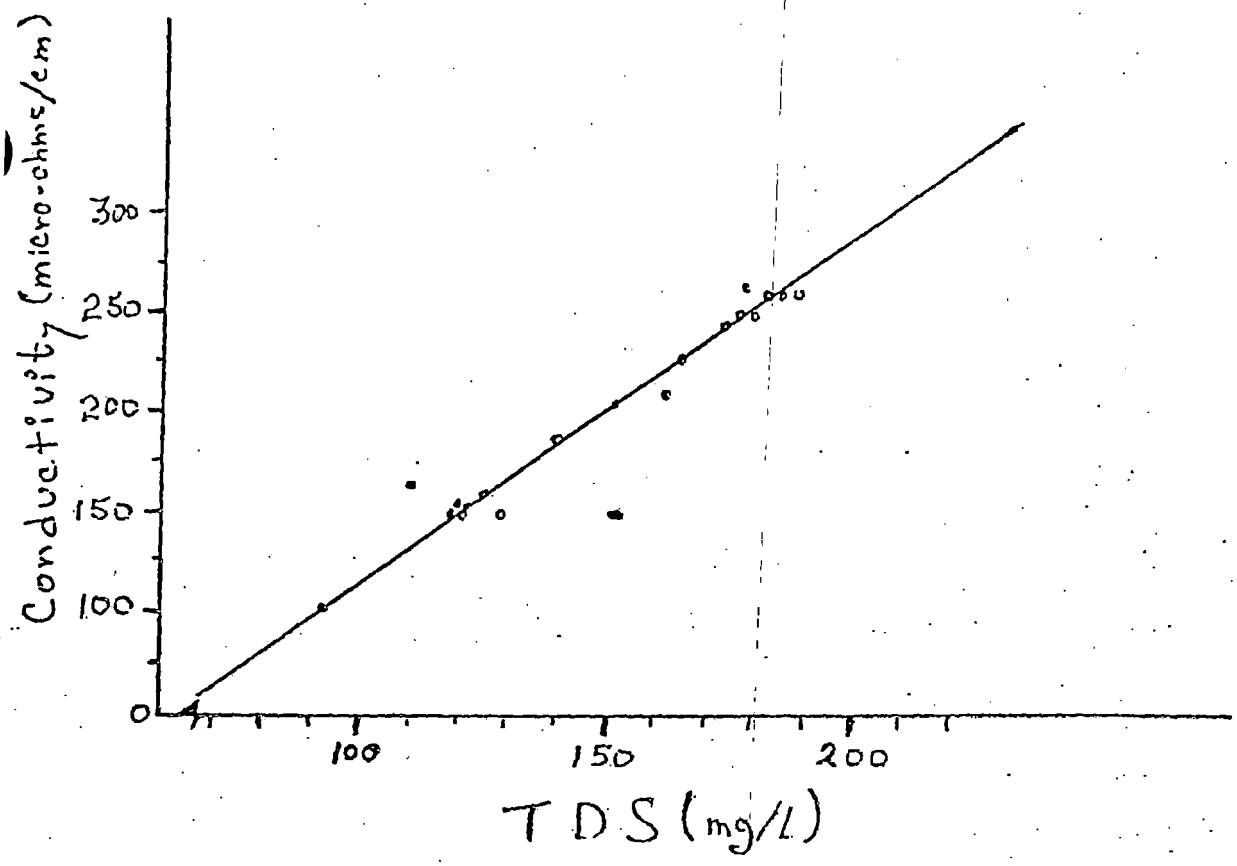


Figure 10. Relationship between conductivity and Total Dissolved Solids in Eagle Creek.

Prong obviously contributed a great deal to the sudden rise of TDS in lower Eagle Creek (Figures 5, 6 and 7), the total amount in Eagle Creek at Four Drag posed no problem for life in the creek and should pose no problems of acclimation for stocked trout.

The bottom composition of Eagle and Chitty Creeks were quite different. Chitty Creek had a large percentage of its substrate in >8 mm sized rocks and less in <.850 cm fines than either location on Eagle Creek (Figure 11). Relative percentage of fines increased from Chitty Creek to East Eagle Creek at Dry Prong to Eagle Creek at Honeymoon Campground. The system appeared to have a large amount (approximately 50% of small <4 mm sized sediment particles. In Big Bonito Creek at 8500 ft. elevation, the percentage of <4 mm particles was approximately 50% in pools, 30% in riffles, and 40% at the spawning sites of Salmo apache (Harper 1976). Thus, the high levels of sediment in Eagle Creek may be a common occurrence in many Arizona watersheds.

Flooding during July and August didn't cause a significant decrease in the percentage of fines (Figure 11). The system appeared relatively stable through the year for percent composition of fines, sand and silt (Figure 11).

Dry Prong Creek appeared to contribute significant amounts of fines (<.850 mm in size) to East Eagle Creek (Figure 12) and the bottom composition of Eagle Creek below Dry Prong

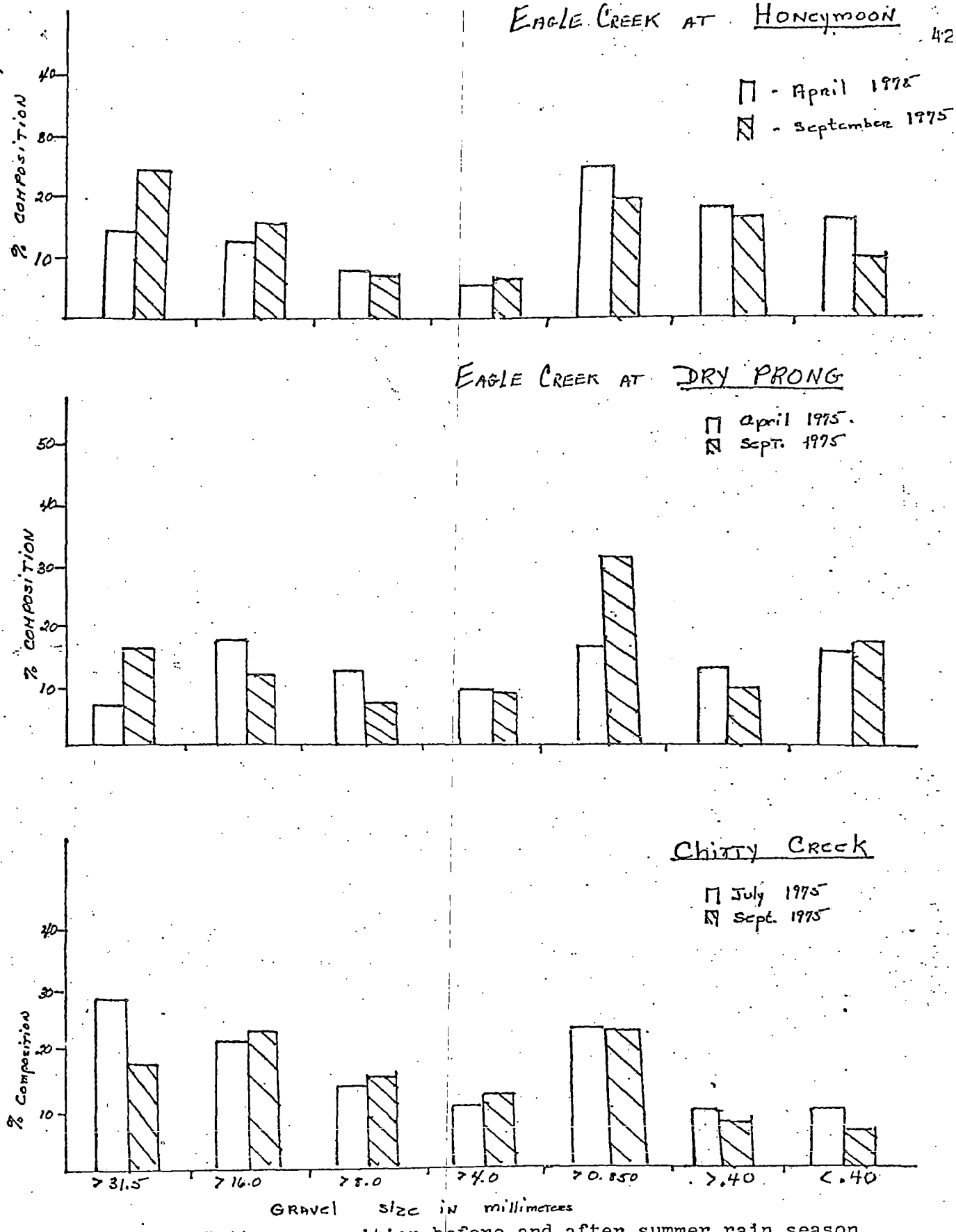


Figure 11. Bottom composition before and after summer rain season. Ten samples were taken at each location before and after summer rains.

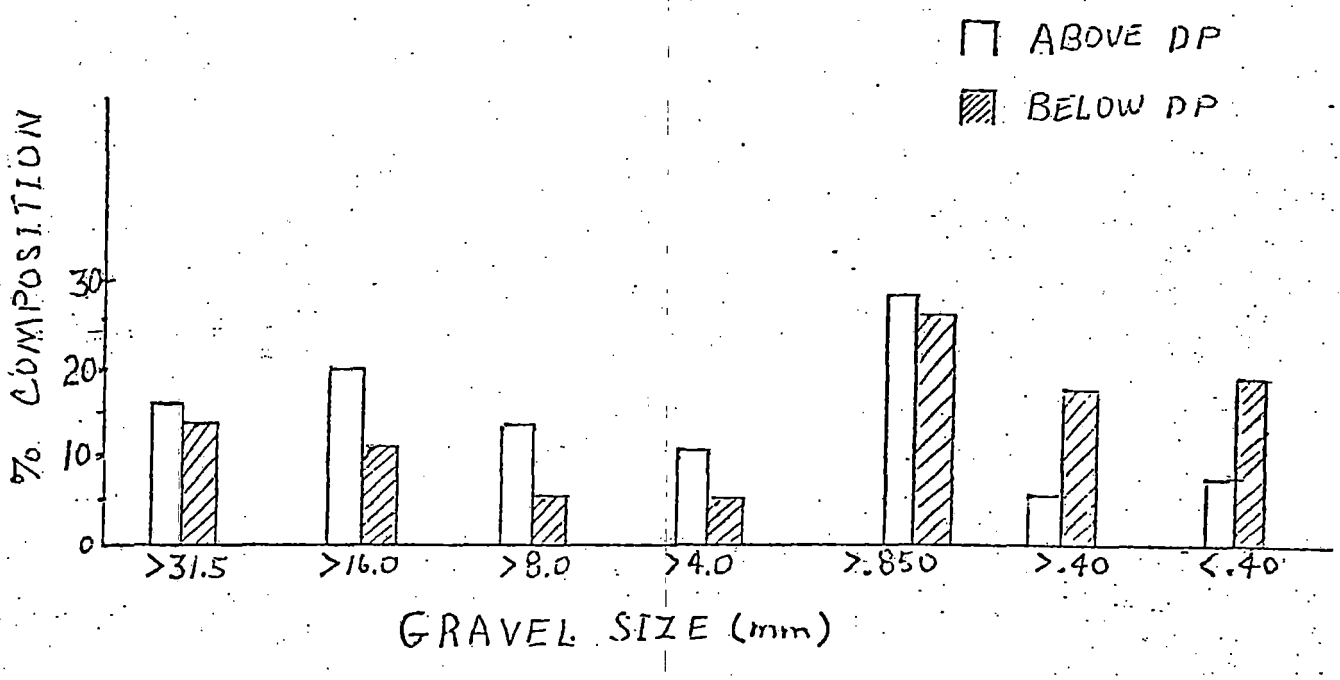


Figure 12. Bottom composition of East Eagle Creek above and below Dry Prong Creek (DP). April and September samples were combined to give 10 samples above and 10 below DP.

Creek differed strikingly from the upstream area. This data was substantiated by observations in August, 1975, during the short time Dry Prong Creek was flowing. The water from Dry Prong was very turbid from the large amount of sediments it brought into Eagle Creek. The watershed drained by Dry Prong must lose many tons of topsoil (the silt and clay of our analysis) each year during runoff from snow melt and rainfall.

Sediment is often defined by fisheries biologists as inorganic particles less than 4 mm (sand, silt, and clay). Some of the effects of these particles on stream salmonids are known (Phillips 1970). When sediment concentrations are as high as those present in Eagle Creek (i.e., 50% <4 mm and 20+% <.850 mm) one can expect several deleterious effects on salmonids, the most important to a resident trout population is the less than 20% survival to emergence of intra-gravel salmonid embryos (Hall and Lantz 1969). Undoubtedly it would have other subtle deleterious effects on both young and adult fish (Phillips 1970).

Under the present summer conditions in Eagle Creek of warm summer temperatures that exceeded recommended maximums for trout waters plus a large sediment load, it would seem that the minimum conditions for a healthy trout population can't be met. If the stream were shaded by planting additional riparian vegetation along Dry Prong and Eagle Creek below Dry Prong perhaps stream temperatures could be lowered enough to

meet trout requirements but successful reproduction in this area is still doubtful. Only four juvenile salmonids were ever captured in Eagle Creek during the study and these could have been displaced downstream from Chitty Creek.

The stocking of catchable sized fish around Easter circumvents the problems caused by temperature and sediment and these fish provide a short but successful fishery according to Arizona Game and Fish. A few fish do over-summer but the habitat on Eagle Creek below Dry Prong is marginal even for adult Rainbow trout. Brown trout would do better temperature-wise in Eagle Creek than Rainbow trout but my experience with Brown trout in the White Mountains of Arizona indicated they would not necessarily make a successful fishery. There is a good probability that they would grow well (lots of native fish prey) and perhaps even reproduce successfully in the stream, but most fishermen couldn't catch them. They would undoubtedly prey on the native fish and could reduce drastically or eliminate some species. No one could predict the eventual outcome on native fish if Brown trout became established in large numbers (as they have in several similar streams in the White Mountains). The same could be said of Smallmouth bass, a warm-water stream game fish. The present stream temperatures are amenable for growth and wellbeing of these fish which have a recommended maximum for growth of 29°C (84°F) (Nemerow 1974) but their growth is stunted in nearby Black

River. Until the reasons for this stunting are explained, it would seem very risky to establish them in Eagle Creek. A successful introduction but unsuccessful fishery would be much worse than no introduction at all because it would be very difficult to get rid of them if they became established in Eagle Creek.

The Eagle Creek area is one of the last remaining semi-natural riparian watersheds with a large healthy native fish fauna in southern Arizona. The present put and take trout fishery seemed to have minimal effects on the system. The establishment of a permanent fishery of Smallmouth bass or Brown trout would probably lead to the eventual demise of some or all of the native fish fauna. In view of the limited habitat for these populations and the unique natural area it would not seem wise to establish Smallmouth bass or Brown trout in Eagle Creek at this time. Instead I would recommend continuing the present fisheries policy of a spring stocking of catchable Rainbow trout and the maintenance of the native fish populations.

Biological Indicators

The results of the benthic macroinvertebrate samples indicated that Chitty Creek was much poorer in abundance and biomass of macroinvertebrates than either location on Eagle Creek (Figure 13). Eagle Creek at Dry Prong had the highest standing crop (total biomass). The mean abundance and weights

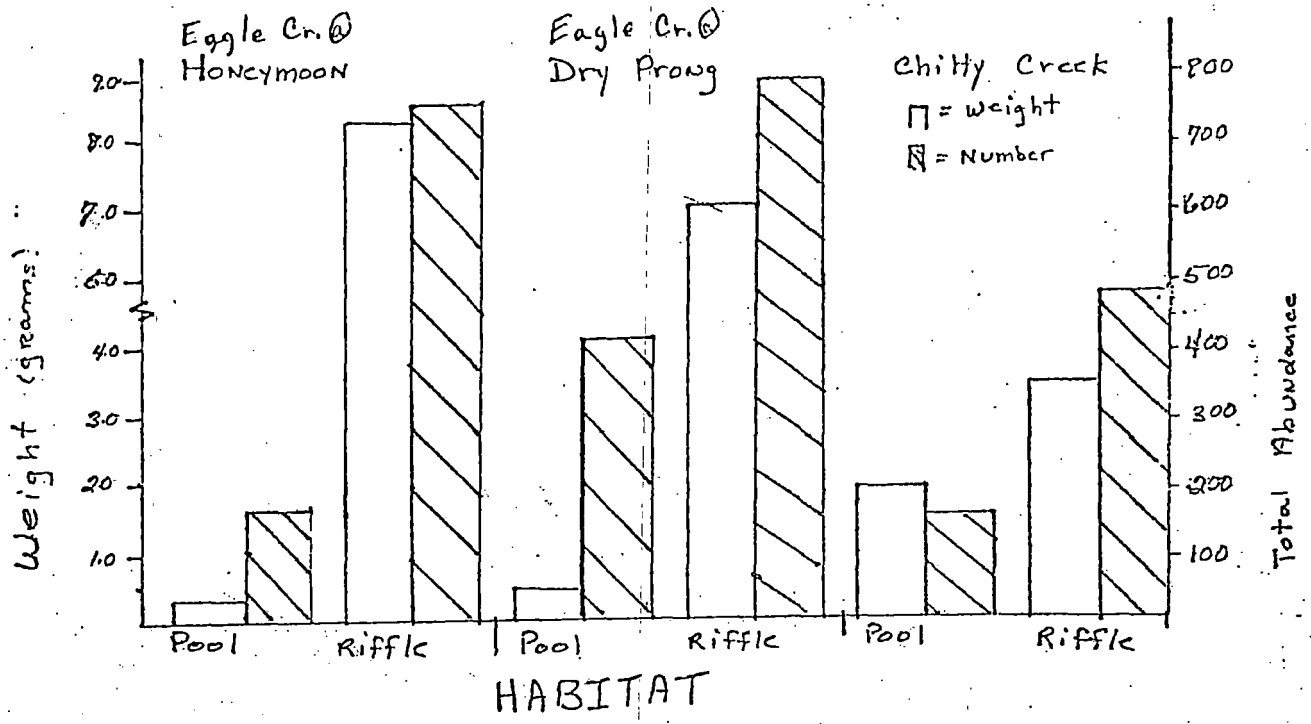


Figure 13. Abundance and relative biomass of macroinvertebrates from pools and riffles in Eagle Creek Watershed.

of invertebrates in the three areas were: Chitty Creek had 61.9 insects/ft^2-(.53 g/ft^2); Eagle Creek at Dry Prong Creek had 118.8 insects/ft^2-(.73 g/ft^2); Eagle Creek at Honeymoon had 90.9 insects/ft^2-(.85 g/ft^2). Although the data are limited, these relative standing crops appeared to be rather low, especially at Chitty Creek, when compared to many other small mountain streams cited by Hynes (1972). Since the substrate controls the abundance and the species present (Hynes 1972), this low standing crop may be related to the large amount of bottom sediment present in these streams. Pennack and Van Gerpen (1947) and Denham (1938) found less benthic invertebrates in sand, silt and clay substrate than in rubble or gravel. In all three areas riffles had larger standing crop than pools (Figure 13). This has been found by other workers (Hynes 1972).

Both locations on Eagle Creek resembled each other for insect families and both were somewhat different from Chitty Creek (Table 1). The Lepidoptera larva which were so abundant in Eagle Creek were not collected in Chitty Creek. There also appeared to be a replacement of tricopteran families between Eagle Creek and Chitty Creek. The Hydropsychidae were the dominant tricopteran in Eagle Creek but the Rhyacophiliade were dominant in Chitty Creek (Table 1).

Twenty-one families of insects were collected at Chitty Creek while Eagle Creek at Dry Prong had 15, and Eagle Creek at Honeymoon had 18. The diversity analysis using the Shannon-Weiner information theory function (i.e., the greater H is,

Table 1. Relative abundance and biomass of macroinvertebrates from three areas on the Eagle Creek Watershed.

Insect Group		Area					
		Eagle Creek at Honeymoon		Eagle Creek at Dry Prong		Chitty Creek	
Order	Family	% Abundance	% wt.	% Abundance	% wt.	% Abundance	% wt.
Ephemeroptera	Baetidae	15.62	6.63	3.96	4.64	5.14	2.24
	Heptageriidae					1.95	.85
Plecoptera	Chloroperlidae					2.65	.48
Tricoptera	Hydropsychidae	25.25	29.39	8.67	15.58	.53	.63
	Psychomyiidae	.22	.13			3.01	1.76
	Rhyacophilidae	.45	.10	4.21	.16	22.87	6.42
	Lepidostomatidae					.71	.40
	Limnephilidae					1.42	25.79
Diptera	Tendipedidae	36.24	.90	68.10	2.65	37.76	.98
	Heleidae	.45	.03	.08	.31	.35	.02
	Stratiomyidae	.22	.01				
	Simuliidae	.45	.06	.17	.05		
	Tabanidae	.45	3.61	.08	1.05	.71	5.81
	Tipulidae					6.56	8.09
	Empididae			.08	.02	.35	.05
	Dolichopodidae			.76	.51	.17	.07
Odonata	Agrionidae	.11	.42	.08	.49		
	Cordulegastridae					.71	27.26
	Aeshnidae					.53	6.62
Lepidoptera	Pyralidae	11.55	41.92	11.28	62.81		
Neuroptera	Corydalidae	.11	.58				
Hemiptera	Belostomatidae	.11	12.95				
Coleoptera	Elmidae	3.51	.14	1.94	1.33	11.34	.48
	Dryopidae	.90	.60	1.35	2.25	1.77	1.94
	Psephenidae					1.06	.49
Oligochaeta		3.91	2.03	.25	.11	.17	.05
Turbellaria		.34	.04				
Mollusca	Physidae	.11	.06	.08	.07		
	Corbiculidae					.17	.52

the greater the species diversity and the larger E is the more even in the allotment of individuals among species) is presented below:

	H	E
Eagle Creek at Honeymoon	2.505	0.601
Eagle Creek at Dry Prong	1.688	0.432
Chitty Creek	3.451	0.786

Invertebrate diversity in Eagle Creek was much lower than diversity in Chitty Creek. Benthic invertebrates in unpolluted waters generally have a "H" of 3 to 4 whereas in severely polluted streams H is less than 1 (Wilhm 1970). EPA biologists found E was more sensitive than H when habitat degradation was slight to moderate. In these cases values for E were generally below .5. The normal range for E in undegraded streams was usually between .6 and .8 (Weber 1973). If these E values are applied to the Eagle Creek Watershed, we come to the same conclusion as we did using macroinvertebrate diversity - Chitty Creek had by far the most undegraded natural community of benthic macroinvertebrates.

The diversity and equitability values in Eagle Creek at Dry Prong were marginal or below the values generally found in undegraded streams by EPA biologists (Weber 1973). Over 68% of the macroinvertebrates found in Eagle Creek at Dry Prong were Dipterans of the family Tendipedidae. Two miles downstream at Honeymoon Campground, the H and E of the benthic invertebrate community had increased to minimum EPA standards and Tendipedidae abundance had decreased to 36%. This Tendipedidae abundance resembled that in Chitty Creek (37%).

Part of the problem in Eagle Creek may be related to the large amount of fine sand and clay particles brought into Eagle Creek by Dry Prong Creek (Figure 12). Chitty Creek had the lowest percent of fine sand or clay and a bottom composition that contained much more rubble and gravel sized substrate. It was also much cooler. This suggests that the decreased H and E in Eagle Creek may be related to degradation of stream habitat caused by increased temperature and/or siltation. Any differences wouldn't seem related to stream size since Chitty Creek is much smaller than Eagle Creek and on the basis of size one would predict higher H in the larger stream. It is also possible that the low H and E values in Eagle Creek only reflect the summer season when the stream was less hospitable than Chitty Creek, i.e., warmer stream temperatures, unstable substrate and flow conditions caused by spates. A seasonal study would help to elucidate this aspect of the results.

The macroinvertebrate insect community appeared quite sensitive to stream degradation by either point or non-point pollution. The results suggested that a similar, perhaps more extensive analysis, should be included in future stream pollution studies. If possible, H and E should be determined more often (seasonally). Also, field situations should be sought where various combinations of degree of streambed sedimentation and stream temperature can be found. In these locations an in-depth study of macroinvertebrate diversity could prove very fruitful.

The five native fishes reported in the Gila River drainage by Miller and Lowe (1964) and Minckley (1973) were still present in 1975-76. We have no data on their relative abundance during the past so no comparisons can be made as to any changes in relative abundance that might have occurred. The fact that native species were still present indicated that, at this time, the habitat changes and possible degradation had not been beyond their capacity to compensate. In addition to the native fish Longfin dace (Agosia chrysogaster), Speckled dace (Rhinichthys osculus), Colorado River chub (Gila robusta), Gila Mountain sucker (Pantosteus clarki), and Gila sucker (Catostomus insignis), there were only a few trout in Eagle Creek (Figure 14). The relative abundance of G. robusta, P. clarki, and C. insignis may be a little low since large individuals of these species were observed in deep pools but these weren't sampled adequately with the electroshocker or seine. Despite this shortcoming, the data indicate that all native species are present in substantial numbers (Figure 14).

Except for A. chrysogaster and R. osculus, the largest numbers of all other species were captured in summer (Figure 15). The relative abundance of the five native species for the three seasons (spring, summer, and winter) indicated that P. clarki was the numerically dominant species (Figure 16). Also it was interesting that P. clarki seemed to occur in all three habitats (riffle, raceway, and vegetated/pools) in large

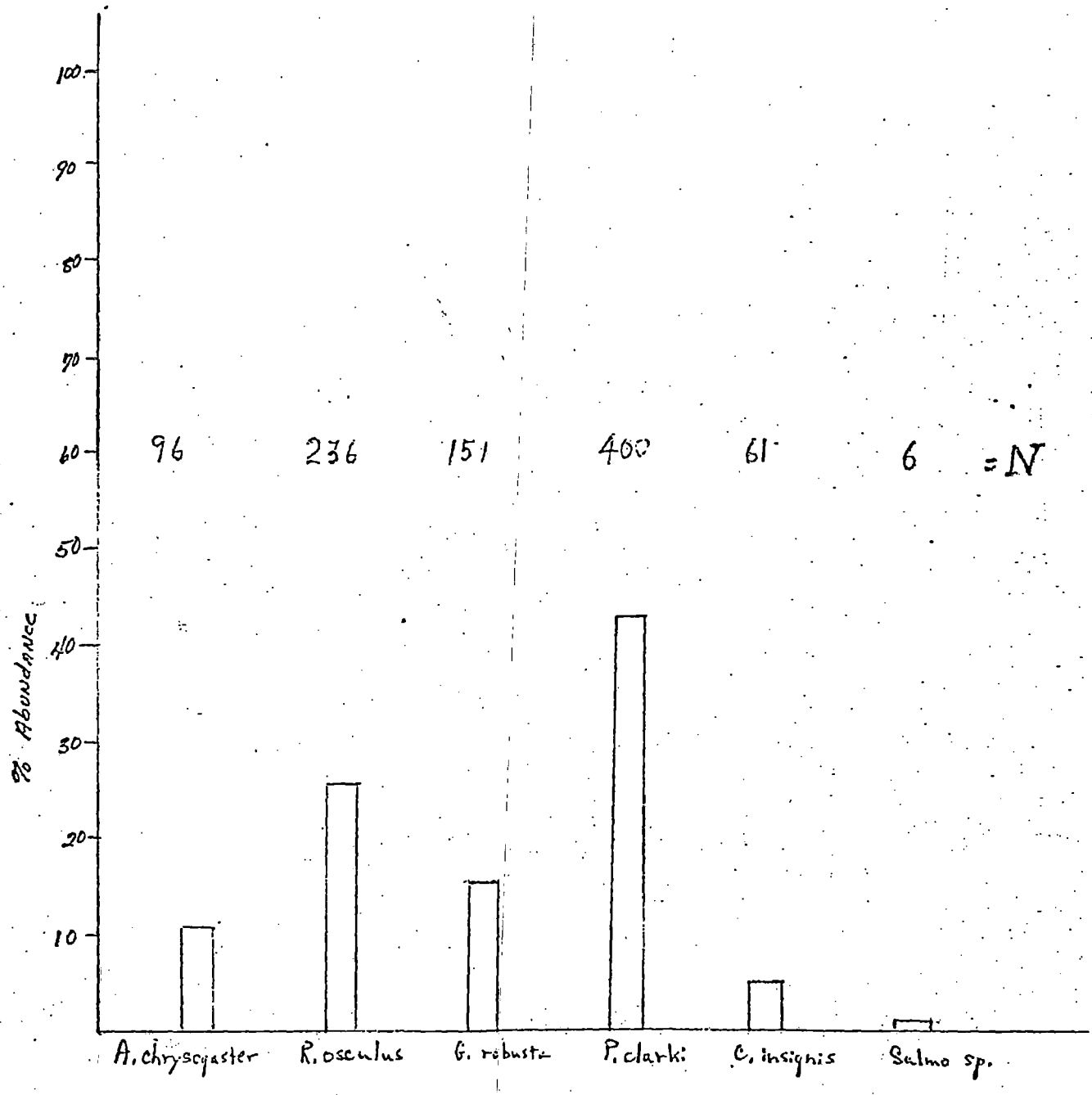


Figure 14. Relative abundance of fish species in Eagle Creek.

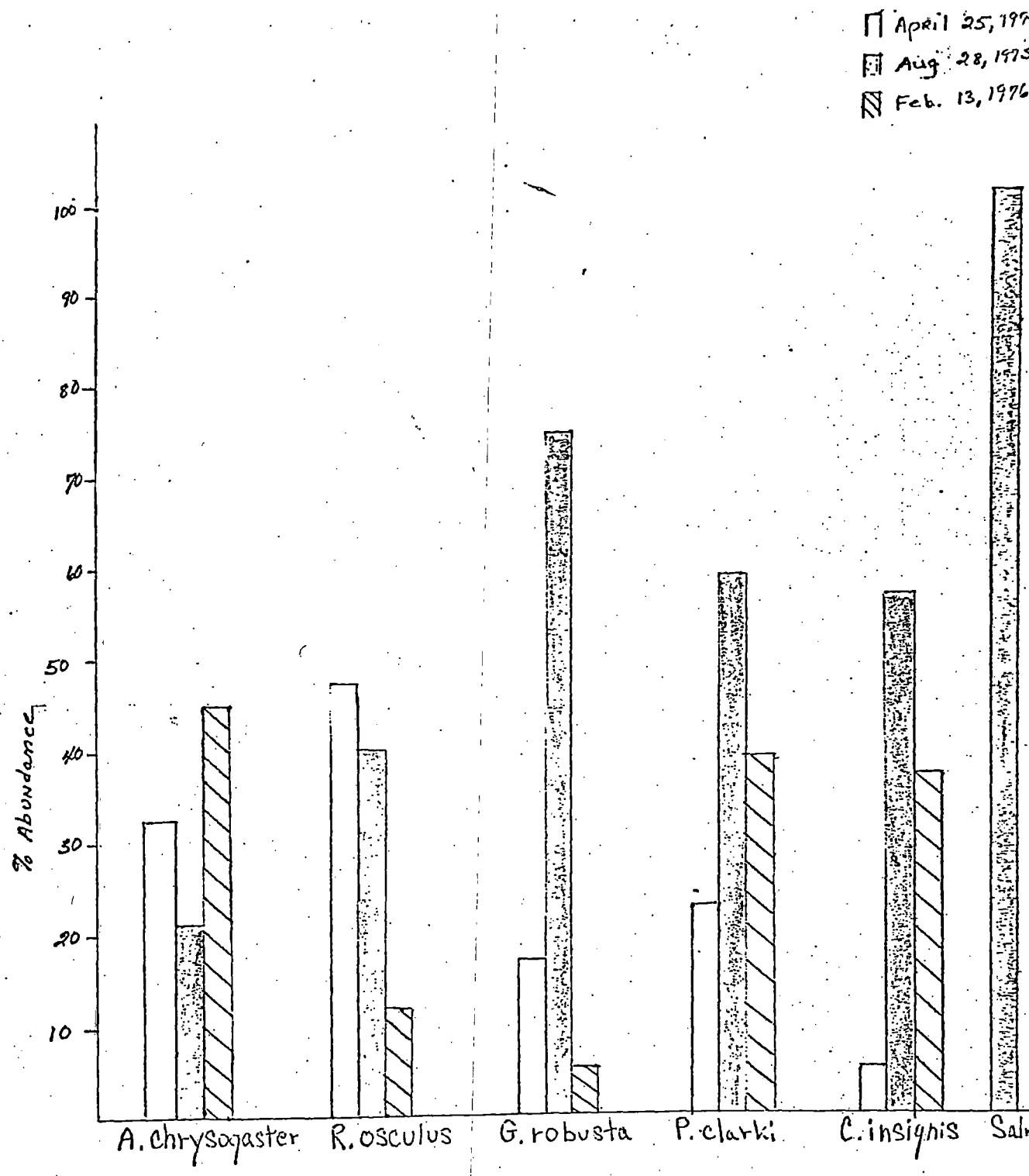


Figure 15. Sampling period when each native fish species was most abundant.

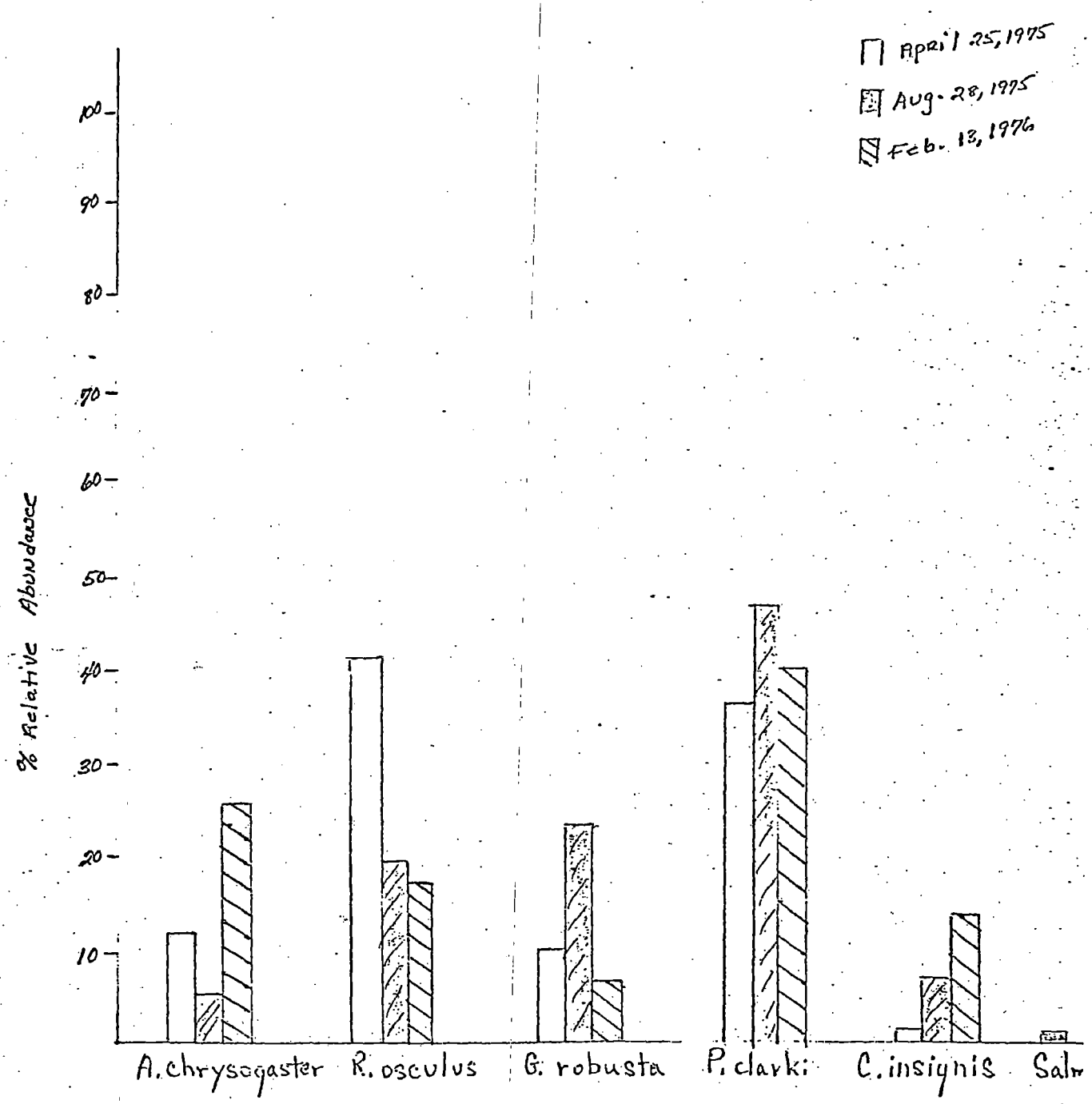


Figure 16. Relative abundance of native fish in catch during April, August, and February.

numbers (Figure 17). This contrasts strikingly with the abundance of A. chrysogaster and G. robusta in the vegetated/pools or the occurrence of C. insignis in the raceway (Figure 17 and Table 2). R. osculus and P. clarki occurred in all three habitats in good numbers.

Length-frequency histograms for each species during the three collection periods are presented in Figures 18, 19, 20, 21, and 22. The importance of the vegetation/pool habitat as a rearing area for young fish of A. chrysogaster, R. osculus and G. robusta can be appreciated by observing the large numbers of small fish that occurred in Dry Prong Creek (Figures 15, 17, 18, 19, and 20). Gila robusta and A. chrysogaster were represented in Dry Prong Creek by good numbers of adult fish also. The length-frequency data also indicated that growth appeared normal, i.e., no stunting of fish was evident and there appeared to be good numbers of young fish that were recruited to the populations of R. osculus, A. chrysogaster, and G. robusta (Figures 18, 19, and 20). The rearing areas and success of recruitment of the young suckers was less clear since length frequency analyses did not reveal any large numbers of small fish (Figures 21 and 22).

The condition factors (K) of the various species during the seasonal sampling periods is presented in Table 3. The data indicated that the three Eagle Creek cyprinid species and two catostomid species had condition factors within the range

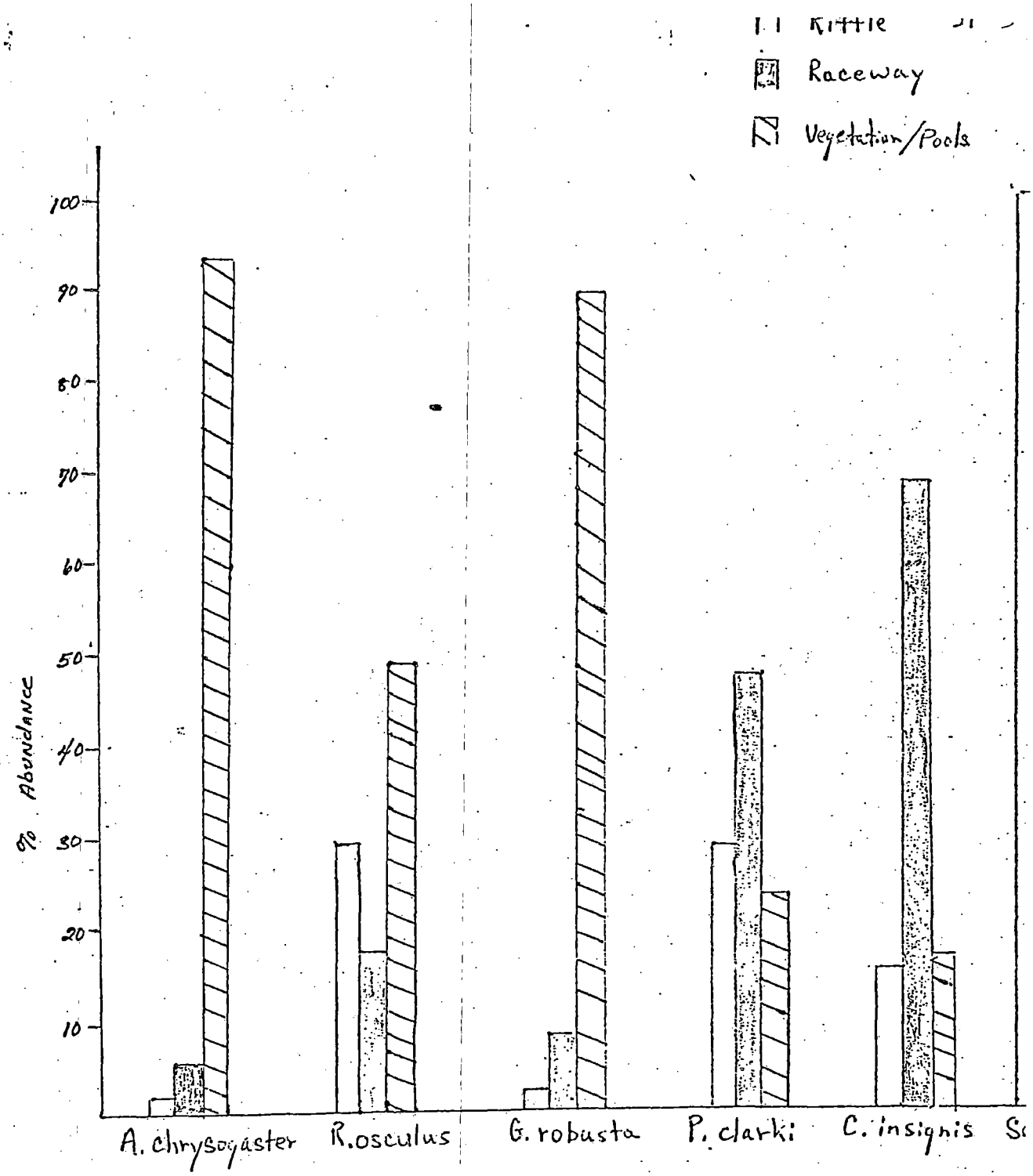


Figure 17. Relative abundance of each species in three habitats.

Table 2. Catch of each species relative to habitat type and season.

Species	Month of Capture								
	April			August			February		
	Habitat			Habitat			Habitat		
	Riffle	Raceway	Veg/Pool	Riffle	Raceway	Veg/Pool	Riffle	Raceway	Veg/Pool
	Number Caught			Number Caught			Number Caught		
Agosia chrysogaster	--	--	31	--	5	16	2	--	42
Rhynichthys osculus	--	21	92	66	21	8	8	--	20
Gila robusta	--	1	26	1	11	103	2	1	6
Pantosteus clarki	5	39	51	83	141	14	28	11	28
Catostomus insignis	3	--	1	2	32	--	4	10	9
Salmo sp.	--	--	--	6	--	--	--	--	--

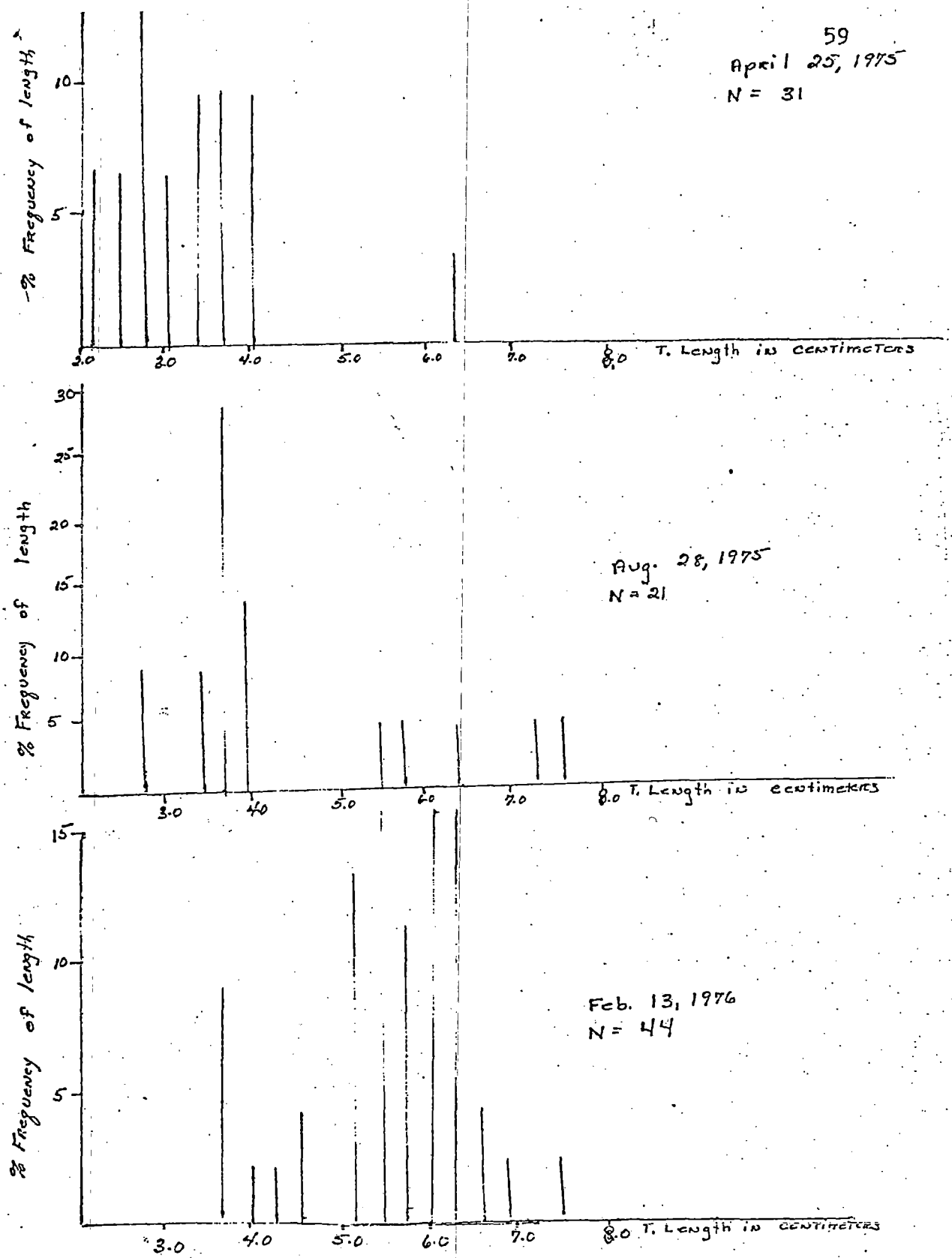


Figure 18. Length frequency histograms of Agosia chrysogaster in 3 mm intervals.

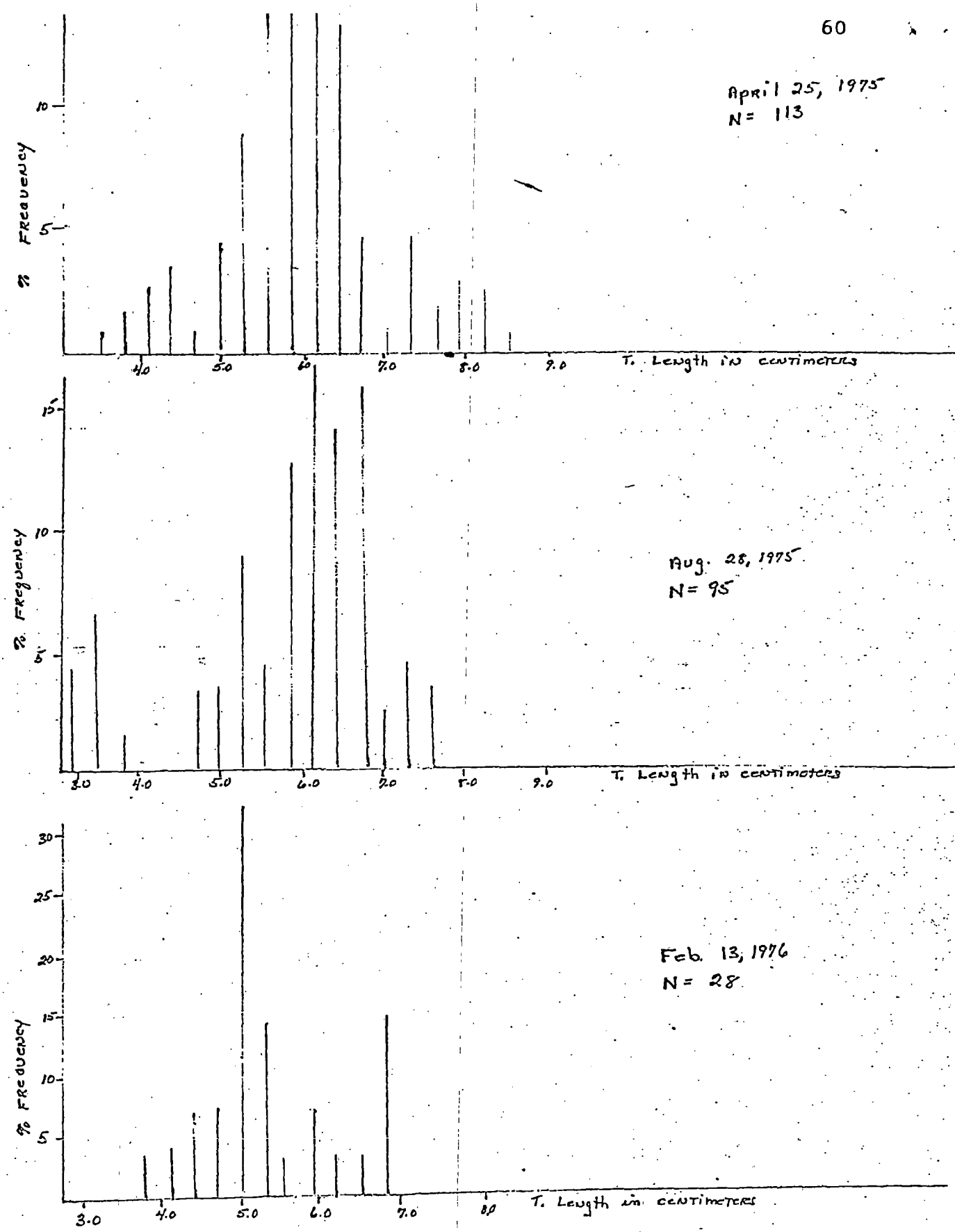


Figure 19. Length frequency histograms of Rhinichthys osculus in 3 mm intervals.

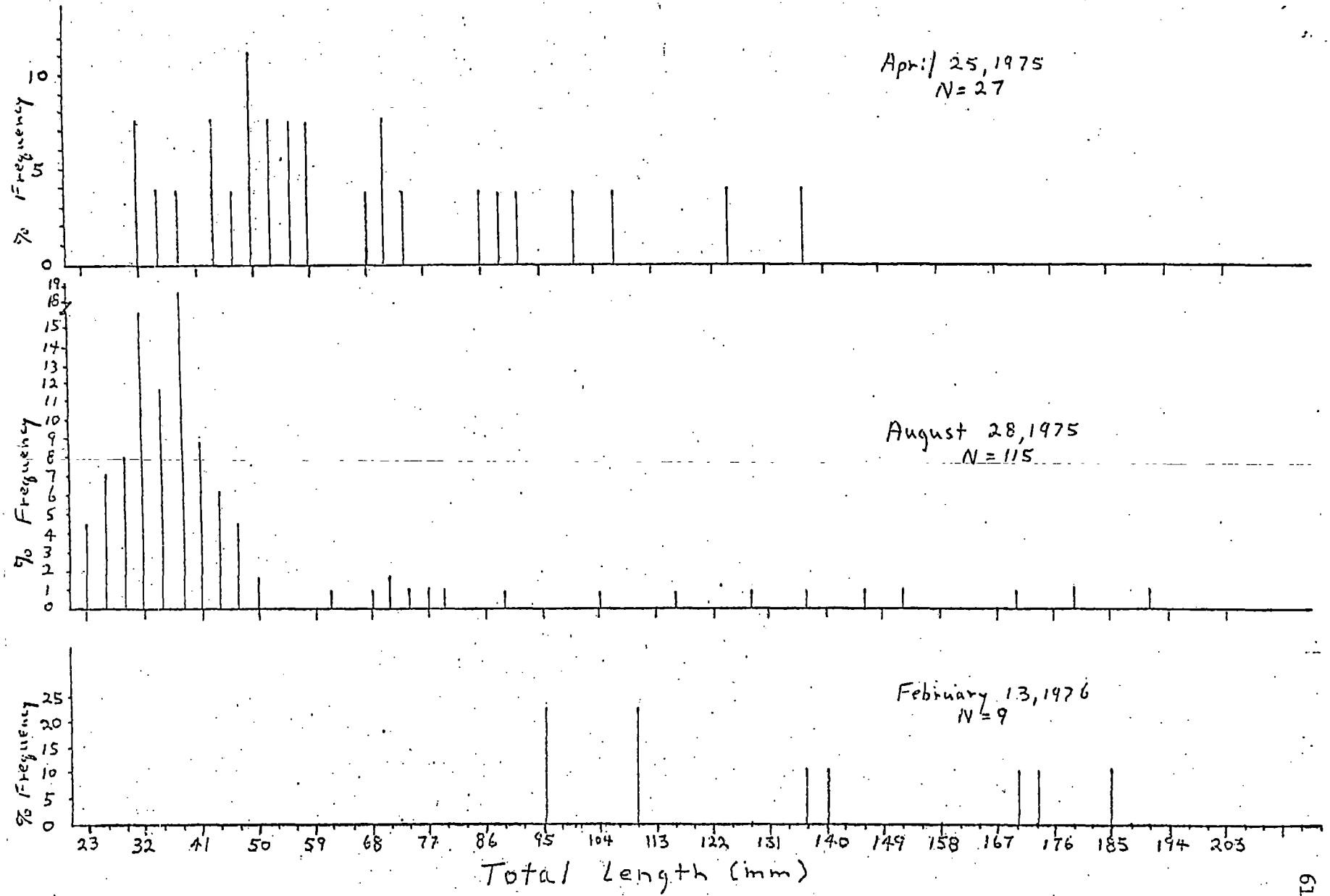


Figure 20. Length frequency histograms for Gila robusta in 3 mm intervals.

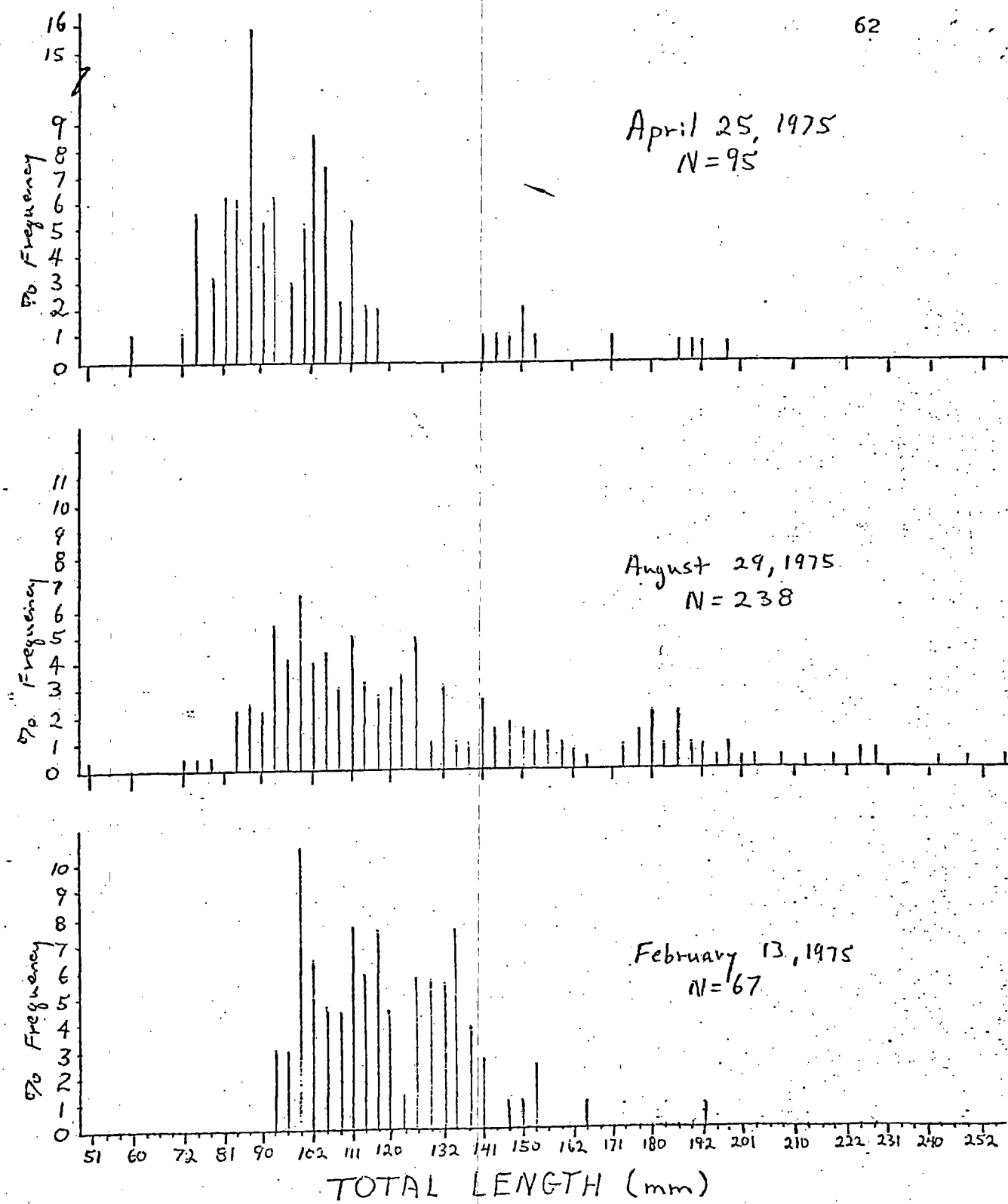


Figure 21. Length frequency histograms of Pantosteus clarki in 3 mm intervals.

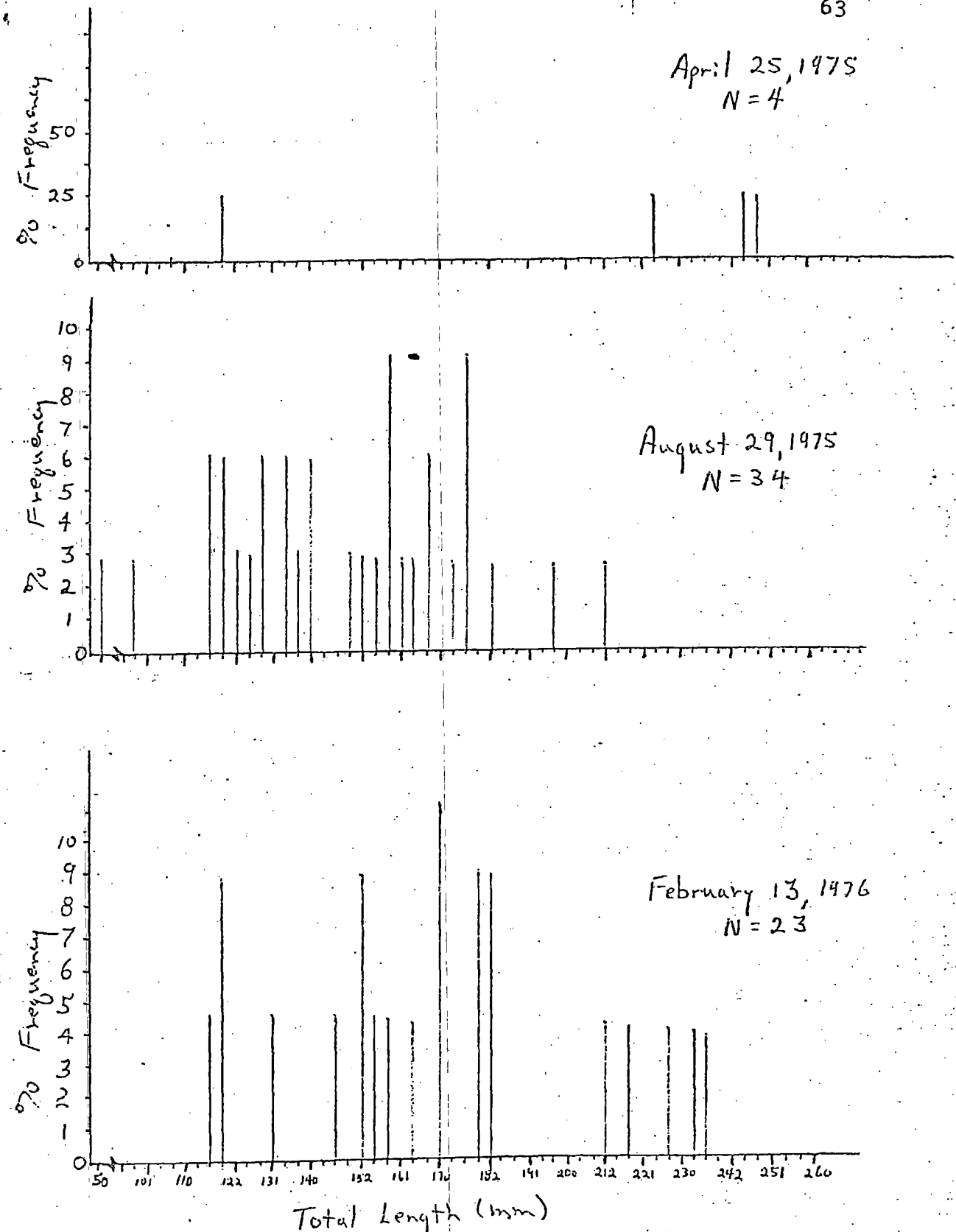


Figure 22. Length frequency histograms of Catostomus insignis in 3 mm intervals.

Table 3. Mean condition factors of each fish species for each sample period.

	April			August			February		
Species	No.	Mean Size (mm)	Mean K	No.	Mean Size (mm)	Mean K	No.	Mean Size (mm)	Mean K
Agosia chrysogaster	--	--	--	21	43.1	1.14	44	57.3	1.38
Rhynichthys osculus	--	--	--	95	57.0	1.26	28	52.5	1.25
Gila robusta	27	63.9	.93	115	44.4	1.02	9	132.7	1.25
Pantosteus clarki	--	--	--	238	127.9	1.41	67	119.3	1.71
Catostomus insignis	4	21.2	1.29	34	139.3	1.30	23	173.6	1.28
Salmo	--	--	--	6	--	1.25	--	--	--

of values reported for similar species elsewhere in the United States (Carlander 1969). Instead of calculating the mean K for all individuals of a particular species for a sample period, it would have been preferable to follow individuals of a known age class through their seasonal variation in condition. Unfortunately this was beyond the scope of the present study. Although the condition factor data would benefit greatly by more rigorous consideration of the various factors that are known to effect K, i.e., stage of fish maturity, sex, and size of fish, it is believed that the data illustrate that native fish in Eagle Creek had normal condition factors. This indicated that the environmental conditions of Eagle Creek provided enough suitable habitat for general wellbeing of the five native species.

Taxonomy of Chitty Creek Trout Results

The results of the graphs of character ratio vs fish size revealed that none of the ratios changed with size of fish in any of the populations. This meant that the character ratios could be used to compare the four populations. Since the Gila trout and hatchery Rainbow trout samples were significantly larger than Chitty Creek trout, this factor was considered a critical point in establishing the validity of such comparisons between these samples of trout. The dorsal spotting (character 12) was found to increase with size of fish in Gila and Chitty Creek trout but not in hatchery Rainbow trout

(HRT). Therefore, the dorsal spot count was omitted from the analysis until it can be standardized.

The Chitty Creek trout population differed statistically from Main Diamond Creek Gila trout, hatchery Rainbow trout, and upper Big Bonito Creek Arizona trout. The discriminant function's mathematical linear analysis placed Chitty Creek trout at a great morphological distance from any of the other Salmo forms (Figure 23). The Chitty Creek trout was closest morphologically to Arizona trout and furthest from Gila trout. This was not expected at all since only recently Miller (1972) concluded that only the Gila trout inhabited the Gila River drainage. The Chitty Creek population wasn't a hybrid population of native trout x hatchery Rainbow trout either. If this were the case, the group centroid for Chitty trout in Figure 23 would show an intermediate relationship between one of the native trouts and hatchery Rainbow trout.

The validity of the discriminant function values that were generated for each fish was upheld when 100% of each fish group was correctly reclassified into its proper group using only the discriminant function values. Eigen values and Wilks-Lambda values both indicated excellent ability of the information in the character ratios to correctly separate the groups. Morphological character ratios that were given highest standardized discriminant function coefficients, i.e., contributed

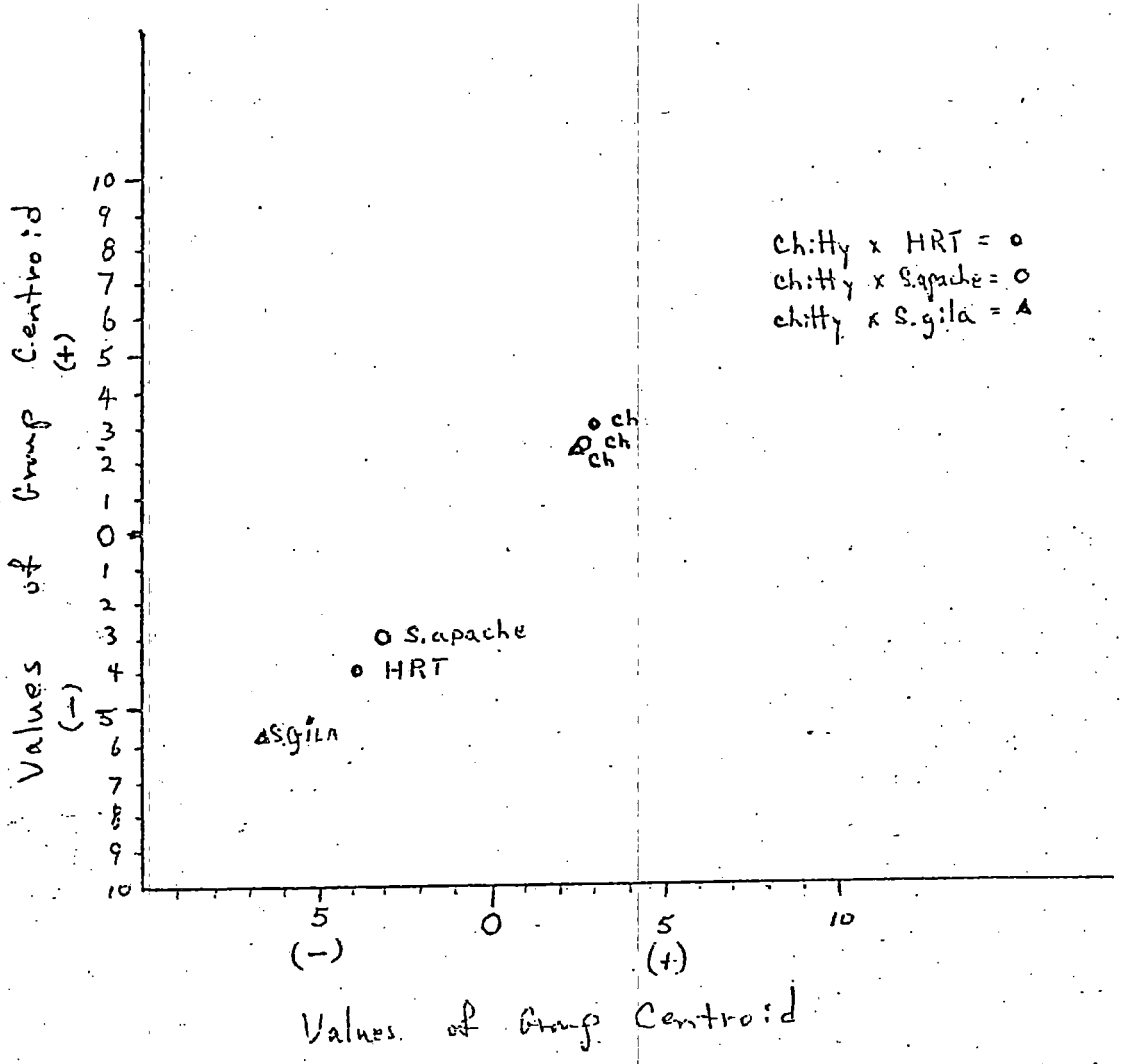


Figure 23. Plot of the mean discriminant scores (group centroids) resulting from comparison of Chitty Creek trout (Ch) with S. apache, S. gilae, and hatchery Rainbow trout (HRT).

most to separating the groups were:

Disc. Func. Importance	Chitty X Arizona Character Ratio	Chitty X Gila Character Ratio	Chitty X HRT Character Ratio
1	9	10	10
2	8	8	8
3	6	9	4
4	5	6	9
5	4	4	7

The results of the t-test comparisons also provided information on the statistical difference between the populations for morphological characters. Significant t-test differences were found between the mean character ratio values of the Chitty Creek fish and most characters of the other populations (Table 4). The five character ratios with the highest t-values for each comparison were:

T-test Importance	Chitty X Arizona Character	Chitty X Gila Character	Chitty X HRT Character
1	7	11	11
2	10	7	5
3	6	10	4
4	4	9	8
5	5	8	9

There were differences between the importance of characters in the discriminant function analysis and the t-test comparisons but there was agreement also. In each case, three of the five characters that were important to the discriminant analysis were also included in the top five characters according to t-test values.

Table 4. Student's t-test values for trout population comparisons. Significant t-test values were $p < .05$ = *; $p < .01$ = **; $p < .001$ = ***. Non-significance indicated by NS.

	Chitty X Arizona	Chitty X Gilae	Chitty X HRT
Character	t-value	t-value	t-value
1	$.60^{NS}$	2.65^{**}	8.92^{***}
2	3.41^{***}	6.85^{***}	1.20^{NS}
3	6.22^{***}	3.81^{***}	$.70^{NS}$
4	4.49^{***}	1.59^{NS}	13.07^{***}
5	3.75^{***}	$.09^{NS}$	13.21^{***}
6	6.93^{***}	$.08^{NS}$	$.37^{NS}$
7	9.20^{***}	12.41^{***}	2.70^{**}
8	2.24^{*}	8.15^{***}	8.39^{***}
9	1.97^{**}	9.56^{***}	8.54^{***}
10	9.23^{***}	9.84^{***}	8.10^{***}
11	2.54^{**}	19.69^{***}	16.00^{***}

The degree of overlap in characters between the populations is usually calculated before any taxonomic determination. Statistical differences are expected in any comparison of allopatric populations, but a large degree of non-overlap in characters usually indicates genetic divergence beyond that expected for the same taxonomic categories. The discriminant function which compared the populations for multiple characters, indicated that when all characters were considered Chitty Creek trout were mathematically distinct from the other populations (Figure 23). But this analysis did not calculate the degree of overlap between the populations. The degree of overlap is quite important when comparing similar allopatric populations. On expects, a priori, there will be many similarities and overlap in characters but most taxonomists accept as the criteria of subspecific separation when 75% of population A differs from 97% of B or, put another way, when 90% of the individuals of population A are different from 90% of the individuals of population B (Mayr, Linsley, Usinger 1953). An approximation of this standard is the Coefficient of Difference (C.D.) and it can be calculated from the formula below:

$$C.D. = \frac{\text{Mean A} - \text{Mean B}}{S.E._A + S.D._B}$$

A C.D. of 1.28 indicates a non-overlap between population A and B of 90%. The C.D. values for the ten character ratios were calculated for the Chitty Creek trout comparisons (Table 5).

Table 5. Comparison of Chitty Creek trout with other trout for the degree of non-overlap (C.D.) in character ratios. Only character ratios with values of 80% or greater are presented in the table.

	Chitty X Arizona		Chitty X Gila		Chitty X HRT	
Character ratio	C.D.	% Non-overlap	C.D.	% Non-overlap	C.D.	% Non-overlap
Predorsal length/TL			1.02	85		
Anal fin length/TL					.93	83
Dorsal fin length/TL					1.65	95
Dorsal fin dep. length/TL					1.63	95
Dorsal fin basal length/TL	.87	81				
Adipose fin length/TL	1.23	90	2.01	99		
Head length/TL			1.16	87	1.16	87
Upper jaw length/TL			1.38	92	1.16	87
Maxillary bone length/TL	1.14	87	1.42	92	1.07	85
Snout length/TL			2.77	100	1.96	98

On the basis of this analysis 90% of the Chitty Creek fish do not show overlap with 90% of the Gila fish for four characters and with HRT for three characters. The coefficient of difference, like the discriminant function analysis indicated the Chitty Creek fish most resembled Arizona trout and not hatchery Rainbow trout or Gila trout. Even though Chitty Creek trout were statistically different for all ten character ratio means from those of Arizona trout, they still showed a significant degree of overlap with Arizona trout as the coefficient of difference analysis indicated. On the basis of the analysis performed in this study the following conclusions were made concerning the Chitty Creek trout population (1) they were not hybridized with Rainbow trout (2) they were not an allopatric population of the Gila trout (3) they were statistically different for most characters from all other close allopatric trout populations, and (4) they were a unique, geographically isolated (allopatric) population of Arizona trout that were differentiated at the subspecific level. The major differences between the Chitty Creek trout and Arizona trout was the smaller adipose fin length (mean ratio of C.Cr.T. = .069 and A.N.T. = .0841 - 90% nonoverlap) and the shorter length of the maxillary bone (mean ratio of C.Cr.T = .092 and A.N.T. - .104 - 87% non-overlap.

Conclusions

I. Habitat Quality - Physico-chemical Factors

1. pH - Monthly values indicated no problems for fish production or other forms of aquatic life. Values during April and May indicated no problem of pH shock to Rainbow trout stocking.

2. Total Dissolved Solids - The amount of total dissolved solids was low for streams in desert areas of Arizona but typical of streams in the White Mountains of Arizona. Dry Prong Creek contributed to a sudden increase in TDS in Eagle Creek. Even so, the amount of TDS appeared to pose no problem for aquatic life.

3. Nitrate-N and Ortho-phosphate - There were never excessive quantities of NO_3-N present in the samples. Ortho-phosphate levels in Chitty Creek were in the range of quantities associated with excessive plant growth. The source of these phosphates was unknown but seemed associated with summer water runoff from the watershed. By the time these waters reach Honeymoon Campground the phosphates are tied up by aquatic and terrestrial plants. No sources of pollution quantities of nitrates or phosphates were found associated with Dry Prong Creek, Four-drag Ranch, or Honeymoon Campground.

4. Dissolved Oxygen - Levels of dissolved oxygen during daytime were always within the range of acceptability even for trout. Nighttime levels were not monitored but might pose some problems in Dry Prong Creek and in Eagle Creek below Dry Prong during periods of low flow in summer.

5. Stream Temperature - On the basis of temperature, Eagle Creek would be classified as a warmwater fisheries stream and Chitty Creek as a coldwater fisheries stream. The present fish fauna bears out this distinction. Whether the present stream temperature regime is warmer than that found in the stream prior to cattle grazing is not known. Nor is it known how much stream cover was lost as a result of grazing. Since early information on stream temperatures do not exist, it is difficult to determine if the stream environment has been degraded by the non-point pollution factor - incident radiation that causes increased stream temperatures.

6. Bottom Sediments - There were very large amounts of small sediments in this watershed. Dry Prong wash is a major contributor of fine sediments to Eagle Creek. Flooding did not clean out the stream bed of fine sediments and bottom composition appeared rather stable during the year.

Chitty Creek had approximately 15-20% fines (< .85 mm) which was similar to Big Bonito Creek at the breeding sites of S. apache (15% were < .85 mm). Eagle Creek locations were 35% to 42% fines. Both Eagle Creek Watershed and Big Bonito Creek Watershed appeared to have very large quantities of material < 4 mm in size. This may be characteristic of Arizona's streams above 6500 ft on grazed watersheds. Unfortunately ungrazed watersheds aren't available for comparison of bottom composition.

II. Habitat Quality - Biological Indicators

1. Benthic Macroinvertebrates - Insect diversity analysis indicated that Chitty Creek was the least degraded aquatic habitat, Eagle Creek at Dry Prong was the most degraded and Eagle Creek at Honeymoon Campground was intermediate in quality. This biological indicator seemed to be pointing to the biological consequences of the changes in bottom composition as a result of increased sedimentation of Eagle Creek at Dry Prong.

2. Native Fish - The five species of native fish in Eagle Creek and the Arizona trout in Chitty Creek appeared to be successfully reproducing populations. All appeared present in substantial numbers.

The Dry Prong Creek area was a major rearing area for three species. Adult sized fish were found in all species and length frequency histogram analysis indicated nothing abnormal in size distributions. Condition factors indicated there was adequate habitat quality to insure the general healthy condition of these species.

III. Taxonomy of Chitty Creek Trout

The population of trout in Chitty Creek were Arizona trout, S. apache. They were differentiated at the subspecific level from S. apache in the White Mountains. This is the first reported subspecies of Arizona trout. Since the entire population exists in only 1.5 mi of stream, they deserve special consideration in future management plans.

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Appendix

Below is a list of the aquatic plants found in Eagle Creek. The following algae were abundant in Eagle Creek at the junction with Dry Prong Creek in November, 1975.

Major green algae	*Stigeoclonian* sp.
Minor green algae	*Spirogyra* sp.
	Ulothrix sp.
Minor blue-green algae	*Oscillatoria* sp.

During the summer of 1975 the following plants were collected and identified from Eagle Creek:

Potamogeton pectinatus

Potamogeton foliosus

Ranunculus aquatilis

Chara globularis